THE UNIVERSITY OF MICHIGAN
MAY 20 1960
ENGINEERING LIBRARY

APPLIED MECHANICS Reviews

A CRITICAL REVIEW OF THE WORLD LITERATURE IN APPLIED MECHANICS AND RELATED ENGINEERING SCIENCE

REVS. 2117-2669 VOL. 13, NO. 5 MAY 1960

GENERAL

Analytical Methods in Applied Mechanics 318
Computing Methods and Computers 319
Analogies 320
Kinematics, Rigid Dynamics and Oscillations 320
Instrumentation and Automatic Control 320
Tables, Charts, Dictionaries, etc. 322

MECHANICS OF SOLIDS

Elasticity 322
Viscoelasticity 326
Plasticity 327
Rods, Beams and Strings 328
Plates, Shells and Membranes 328
Buckling 331
Vibrations of Solids 331
Wave Motion and Impact in Solids 333
Soil Mechanics: Fundamental 334
Soil Mechanics: Applied 334
Processing of Metals and Other Materials 334
Fracture (Including Fatigue) 335
Experimental Stress Analysis 336
Material Test Techniques 337
Properties of Engineering Materials 338
Structures: Simple 339
Structures: Composite 341
Machine Elements and Machine Design 341
Fastening and Joining Methods 343

MECHANICS OF FLUIDS

Rheology 343
Hydraulics 344
Incompressible Flow 346
Compressible Flow (Continuum and Noncontinuum Flow) 348
Boundary Layer 353
Turbulence 355
Aerodynamics 355
Vibration and Wave Motion in Fluids 356
Fluid Machinery 358
Flow and Flight Test Techniques and Measurements 360

HEAT

Thermodynamics 363
Heat and Mass Transfer 365
Combustion 369
Prime Movers and Propulsion Devices 370

COMBINED FIELDS AND MISCELLANEOUS

Magneto-fluid-dynamics 371
Aeroelasticity 373
Aeronautics 374
Astronautics 375
Ballistics, Explosions 376
Acoustics 377
Micromeritics 378
Porous Media 380
Geophysics, Hydrology, Oceanography, Meteorology 381
Naval Architecture and Marine Engineering 384
Friction, Lubrication and Wear 384

Books Received, 384

Flow Through Porous Media, A. E. Scheidegger, 313

APPLIED MECHANICS Reviews

Published Monthly by THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS at Easton, Pa., and edited by Southwest Research Institute with the co-operation of Linda Hall Library.

Under the Sponsorship of

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

THE ENGINEERING FOUNDATION

SOUTHWEST RESEARCH INSTITUTE

OFFICE OF NAVAL RESEARCH

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (ARDC)

NATIONAL SCIENCE FOUNDATION

Industrial Subscribers

AMERICAN MACHINE AND FOUNDRY COMPANY

THE BABCOCK & WILCOX COMPANY

BORG-WARNER CORPORATION

CATERPILLAR TRACTOR COMPANY

FORD MOTOR COMPANY

GENERAL DYNAMICS CORPORATION

GENERAL MOTORS CORPORATION

M. W. KELLOGG COMPANY

SHELL DEVELOPMENT COMPANY

STANDARD OIL FOUNDATION, INC.

UNION CARBIDE CORPORATION

UNITED AIRCRAFT CORPORATION

UNITED SHOE MACHINERY CORPORATION

WESTINGHOUSE ELECTRIC CORPORATION

WOODWARD GOVERNOR COMPANY

APPLIED MECHANICS REVIEWS, May 1960, Vol. 13, No. 5. Published Monthly by The American Society of Mechanical Engineers at 20th and Northampton Streets, Easton, Pa., U. S. A. The editorial office is located at the Southwest Research Institute, San Antonio 6, Texas, U. S. A. Headquarters of ASME, 29 West 39th St., New York 18, N. Y., U. S. A. Price $2.50 per copy, $25.00 a year. Changes of address must be received at Society headquarters seven weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-laws: The Society shall not be responsible for statements or opinions advanced in papers or printed in its publications (B13, Par. 4). . . . Entered as second-class matter, January 11, 1948, at the Post Office at Easton, Pa., under the Act of March 3, 1897. ©Copyrighted, 1960, by The American Society of Mechanical Engineers.

EDITORIAL ADVISOR
Martin Goland

EDITOR
Stephen Juhasz

HONORARY EDITORS
H. L. Dryden T. von Karman S. Timoshenko

ASSOCIATE EDITORS
H. Norman Abramson P. M. Ku
E. Carafoli William A. Nash
G. Herrmann J. C. Shipman
K. Washizu

ASSISTANT EDITORS
S. Gardiner S. Lechtman L. Nevin
L. Graf D. Wick

PRODUCTION EDITOR
J. Harrell Aronson

PUBLICATIONS BUSINESS MANAGER
S. A. Tucker

OFFICERS OF ASME
Walker L. Cisler, *President* E. J. Kates, *Treasurer*
O. B. Schier, II, *Secretary*

ASME PUBLICATIONS COMMITTEE
B. G. A. Skrotzki Hendley N. Blackmon
R. D. Mindlin Martin Goland
Vito L. Salerno

HOW TO OBTAIN COPIES OF ARTICLES INDEXED: See section after Books Received for Review.

Editorial Office: **APPLIED MECHANICS REVIEWS, Southwest Research Institute, 8500 Culebra Road, San Antonio 6, Texas, U. S.**
Subscription and Production Office: **The American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y., U. S.**
Depository: **Linda Hall Library, 5109 Cherry Street, Kansas City, Missouri**

APPLIED MECHANICS REVIEWS

Vol. 13, No. 5 May 1960

FLOW THROUGH POROUS MEDIA

A. E. SCHEIDEGGER

IMPERIAL OIL LIMITED, CALGARY, CANADA

1. INTRODUCTION

The study of flow through porous media is of importance in connection with many engineering applications. Such diversified fields as soil mechanics, ground water hydrology, petroleum engineering, water purification, industrial filtration, ceramic engineering and powder metallurgy, all rely heavily upon it as basic to their individual problems. All these branches of engineering have contributed a vast amount of literature on the subject.

The theory of flow through porous media is now accessible in a series of textbooks. The first is a book by Muskat (1) published in 1937. It treats the flow of homogeneous fluids only. The second is a very concise book by Leibenzon (2) which gives a review of results up to 1947. The third is a textbook by Polubarinova-Kochina (3) which deals mainly with solutions of Darcy's differential equation for a great variety of conditions, after using intricate analytical methods. Finally, the writer (4) has written a monograph on the physics of flow through porous media which reviews the status of the subject up to recently.

Pertinent information is also contained in textbooks which were written in connection with the various engineering applications mentioned above. Particularly noteworthy in this regard are the books by Carman (5) on the flow of gases through porous media, by Muskat (6) on the physical principles of oil production, by Lykov (7) on molecular transport phenomena in porous media, and by Todd (8) on ground water hydraulics. None of these special-purpose textbooks, however, attempt to present a *complete* account of the subject.

The present review will stress some of the highlights of the physics of flow through porous media. We begin with a definition of porous media, then discuss the law of Darcy, which is the flow law mostly used in connection with engineering applications. Following this, we shall discuss some of the limitations of Darcy's law and theoretical models of porous media. Finally, a brief account will be given of displacement processes.

2. POROUS MEDIA

The materials with which we are concerned in this review are called "porous media." One might be tempted to define "porous media" as solid bodies that contain "pores," it being assumed as intuitively quite clear what is meant by a "pore." However, it is not as easy as it might appear at a first glance to give an exact definition of a "pore."

Intuitively, "pores" are void spaces which must be distributed more or less frequently through the material if the latter is to be called "porous." Extremely small voids in a solid are called "molecular interstices," very large ones are "caverns." "Pores" are somewhere in between these limits; the limitation of their size is rather intuitive.

The problem of complete geometrical characterization of a porous medium has not yet been solved. Thus, if a photograph be taken of a section of a porous medium, there is no way to represent what is seen on the latter by a series of numbers. Of course, the space bounded by the walls of the pores in a porous medium forms, geometrically, an intricate *surface*. If it were possible to give the "equation" of this surface, the porous medium would be characterized. Unfortunately, porous media are far too complex for this to be possible.

However, one is able to define some geometrical parameters of a porous medium which are based on averages. The first of these is the *porosity P* which is equal to the average ratio of void volume to bulk volume of the porous medium. It is a dimensionless quantity. The second is the specific surface area *S* which is the average ratio of internal surface to bulk volume of the porous medium. It has the dimension of a reciprocal length.

It would be most desirable to have a quantity that would characterize the size of pores. Unfortunately, this poses a serious difficulty. Pores often have the form of tubes so that one cannot speak of their "greatest" dimension. A term commonly referred to is the "diameter" of a pore, which is a somewhat intuitive quantity. It may be given a somewhat more definite meaning if the porous medium is replaced by a theoretical model consisting of a bundle of capillaries (cf. Sec. 5); the size of the capillaries that produces the effect under consideration (such as an observed capillary-pressure curve) is the "pore size" of the medium.

With the above geometrical equipment, one is able to study the flow of fluids through porous media.

3. DARCY'S LAW

About a century ago, Henri Darcy (3) made some experiments to investigate the flow of water through the sand filters of the water purification plant at Dijon. A modern description of these historic experiments may be found in an article by

Hubbert (10). Based upon his experiments, Darcy formulated a law for the flow of a fluid through a porous medium which states that the total volume of fluid percolating in unit time is proportional to the cross-sectional area of the medium, proportional to the difference in hydraulic head between inlet and outlet, and inversely proportional to the distance between inlet and outlet.

"Darcy's law" as formulated above refers to macroscopic quantities, such as differences of heads over a finite distance, and hence only applies to linear flow systems. Also, it states nothing about the constant of proportionality. What is known today under the name of "Darcy's law" is something quite different. This is

$$\mathbf{q} = -(k/\mu)\,(\text{grad}\ p - \rho\mathbf{g}) \qquad [1]$$

where $\mathbf{q}$ is the filtration velocity (this is the quotient of the total volume of flow per unit time through an infinitesimal cross section of porous medium divided by that cross section), μ is the viscosity of the fluid, p is the pressure in the fluid, ρ is the density of the fluid and $\mathbf{g}$ is the gravity vector (of magnitude g and direction downward). Finally, k has been termed the "permeability" of the porous medium.

The original form of Darcy's law as formulated by Darcy follows by an integration from the "modern" form [Eq. 1] for a linear, homogeneous system, but it should be noted that the converse is *not* true. The "modern" and "original" forms of the law are thus not equivalent formulations. *First*, the proportionality constant is specified more precisely in the modern form inasmuch as the "permeability," supposedly a property solely of the porous medium, has been introduced. This was done by Nutting (11) and gained general acceptance after the concept had been put to successful use by Muskat (1) in connection with the study of the physics of petroleum production from underground strata. *Second*, the constant of Darcy's law could be put into a different position in the differential formulation. Thus, one could write

$$\mathbf{q} = -\,\text{grad}\ (kp/\mu) + k\rho\mathbf{g}/\mu \qquad [2]$$

which, upon integration for a linear, homogeneous system, would again lead to the original formulation of Darcy's law. A decision as to which form of the two differential formulations of Darcy's law should be preferred cannot be made upon theoretical grounds (notwithstanding claims to the contrary). However, if the concept of permeability be extended to immiscible multiple phase flow, experimentation shows that the first form [Eq. 1] gives a better description of the observed phenomena than the second [Eq. 2]; it is therefore to be preferred.

The differential formulation of Darcy's law given in Eq. [1] applies to an isotropic, incompressible medium. It can be extended to anisotropic and compressible media. In an anisotropic medium, the permeability becomes a symmetric tensor (12); the law then reads

$$\mathbf{q}_i = -(k_{ij}/\mu)\,(\partial p/\partial x_j - \rho g_j) \qquad [3]$$

where the summation convention has been applied. In compressible porous media, the problem becomes very complicated, inasmuch as the deformation of the porous medium and the flow of the fluid have to be studied simultaneously. Problems of this kind occur in soil mechanics where the consolidation of soil is of interest. Such theories of consolidation have been advanced by Biot (13, 14), Florin (15) and by Barenblatt and Krylov (16). The final equations of consolidation theory are concerned with the bulk mass of the medium. If the flow of the fluids is of primary interest, the latter has to be re-introduced after the solution of the consolidation problem, and a new set of differential equations has then to be solved. If one has applications to underground strata in mind, it is often possible to make certain simplifications in the theory of consolidation. The displacements due to consolidation are usually small compared with those due to the flow of fluid. Furthermore, it is often possible to predict the general manner in which the consolidation will occur (viz. in the vertical direction). This leads to a problem of tractable dimensions (17).

In order to apply the basic equations of flow through porous media to practical cases, the former have to be integrated under the required boundary conditions. In the general case of non-steady-state flow of a compressible fluid through a porous medium, the system of differential equations is nonlinear. The motion of the fluid is fully determined if, in addition to "Darcy's law" [Eq. 1], one has a continuity condition

$$-P\,\frac{\partial \rho}{\partial t} = \text{div}\ (\rho\mathbf{q}) \qquad [4]$$

(where, in addition to the symbols already defined, P is the porosity and t time) and an equation of state for the fluid

$$\rho = \rho\,(p) \qquad [5]$$

As is evident, the above system of equations is non linear, which makes it difficult to obtain solutions.

Solutions where this nonlinearity has been taken into account have for instance been obtained on an electronic digital computer by Aronofsky and coworkers (19, 21) who studied the flow of gases through porous media. Fortunately, however, it is often possible to linearize the system of basic equations.

In this case it reduces to a heat conductivity equation for which many solutions are known (see Carslaw and Jaeger, 22). A great number of solutions of the heat conductivity equation have been adapted to practical problems of flow through porous media; for a list of references the reader is referred to the writer's book (4). Under steady-state conditions the differential equation of flow through porous media becomes even simpler than the heat conductivity equation: it then reduces to a Laplace equation.

A peculiar problem occurs if one studies gravity flow with a free surface in a porous medium. The free surface is an equipressure surface and any streamline having one point in common with it must lie entirely within it. If the free surface intersects an "open" surface of the porous medium, then a surface of seepage will be formed below the line of intersection. The problem of finding the free surface, even under steady-state conditions, is thus one with a floating boundary condition. Various analytical methods have been adapted to this end; the most comprehensive survey will probably be found in the monograph by Polubarinova-Kochina (3) mentioned earlier.

All in all, the number of papers containing solutions of Darcy's law that have been published is huge (about one thousand) so that no detailed references can be given here. For further study, the reader is referred to the monographs cited in the Introduction.

4. LIMITATIONS OF DARCY'S LAW

Darcy's law as discussed above appears to give an adequate description of flow through porous media under a wide variety of conditions. However, it must be expected that there are limitations. It turns out that Darcy's law is valid only in a certain seepage velocity domain outside which more general flow equations must be used to describe the flow correctly.

In order to characterize this seepage velocity domain, it is customary to introduce a Reynolds number as follows

$$Re = q\rho\delta/\mu$$

where, in addition to the symbols defined earlier, δ is a microscopic diameter associated with the porous medium ("pore diameter").

The occurrence of the quantity δ in the definition of the Reynolds number at once poses certain problems, inasmuch as it cannot be properly defined (see Sec. 2). Notwithstanding this difficulty, many investigations have been attempted to establish a "critical" Reynolds number above which Darcy's law would no longer be valid. The contention was, of course, that there exists a universal critical Reynolds number above which the flow in the pores would become "turbulent." In these investigations, a great discrepancy regarding the universal critical Reynolds number became evident; the values range between 0.1 (Ref. 23) and 75 (Ref. 24). This great uncertainty seems to indicate that Reynolds numbers being equal does not assure similarity of the flow in two different porous media.

Notwithstanding anything said above, it is a fact that Darcy's law breaks down at "high" flow velocities. Forchheimer (25) suggested that Darcy's law be modified for high flow velocities by including a second-order term in the velocity, which leads to (in a linear system)

$$\frac{\partial p}{\partial x} = aq + bq^2 \qquad [6]$$

The Forchheimer relation has been further generalized by Polubarinova-Kochina (3) to contain a time-dependent term which leads to (in a linear system)

$$\frac{\partial p}{\partial x} = aq + bq^2 + c\,\frac{\partial q}{\partial t} \qquad [7]$$

In addition to the equations given above, a great number of empirical flow equations have been proposed in the literature. They are usually put into the form of a "correlation" between the Reynolds number and a suitably defined "friction factor." A good review of these correlations has, for instance, been given by Romita (26).

The equation given above as well as the correlations postulated in the literature all exhibit the feature of nonlinearity. It has been generally contended that the breakdown of Darcy's law is due to the onset of turbulence in the pores as this is known to occur in pipes. However, it is well-known that turbulence in pipes occurs at a Reynolds number of approximately 2000. In porous media, a breakdown of Darcy's law occurs at much lower Reynolds numbers (even if the latter is calculated with the "pore-velocity" $v_p = q/P$ rather than the seepage velocity q) which indicates that an entirely different cause of nonlinearity is effective. It has been noted by Irmay (27) that the influence of inertia effects will always lead to nonlinear equations of the type of Eq. [6] or Eq. [7] whether these inertia effects be manifest in turbulence or some other phenomena. In view of the Reynolds numbers being so small, it is inconceivable that turbulence plays any role at all. Inertia effects, however, will also become manifest in curved channels in *laminar* flow. It stands to reason, therefore, that the breakdown of Darcy's law is caused by the nonlinearity in the flow equations describing laminar flow in curved channels. Of course, if the flow velocity is increased beyond limit, true turbulence (i.e. statistical velocity fluctuations) will eventually set in.

Solutions of the above high-velocity flow equations for particular cases are difficult to obtain. Notwithstanding the difficulties, Engelund (28) discussed some of the possibilities.

A breakdown of Darcy's law also occurs in gases at low pressures. This is due to the various molecular effects that may come into prominence in rarefied gas dynamics (see Schaaf (29)). Thus, one has the possibility of Knudsen (slip) flow and even of molecular flow occurring. Furthermore, if the gas molecules are strongly adsorbed by the porous medium, additional effects may occur. The gas forms a surface layer in which surface flow may be much more rapid than in the interior of the pores. In the flow equation, this effect adds a surface flow term to the molecular and Darcy terms. The situation has been particularly well described in the book of Carman (5).

Solutions of the system of differential equations describing gas flow with molecular and surface effects are again very difficult to obtain, owing to the nonlinearity involved. Collins and Crawford (30) showed how the system can be adapted to make it amenable to treatment with high-speed electronic computers and, based upon their work, Aronofsky (31) actually carried out some calculations for specific cases.

Apart from the phenomena mentioned above, there are some others that can cause a breakdown of Darcy's law. Chief among these are electrical effects owing to the presence of ions in the percolating fluid. This leads to the phenomenon of "counter-electroosmosis" (cf. Refs. 32, 33). Another group of anomalies has been ascribed to a "boundary effect" which causes the velocity of a fluid stream to decrease near the wall of the bed. For details, the reader is referred to papers by Zhavoronkov (34) and Schwartz (35).

5. THEORETICAL MODELS OF POROUS MEDIA

The flow laws discussed above are essentially empirical laws, deduced from a series of experiments. However, since the fluids flowing through a porous medium can in most instances be regarded as ordinary, Newtonian, viscous fluids, it should be expected that their motion can be described by obtaining a suitable solution of the Navier-Stokes equation. This could be done if it were possible to formulate correctly the boundary conditions of the problem, stating that the fluid must stick to the walls of the pores. Unfortunately, as we have noted (see Sec. 2), porous media are of an extremely complex nature. Correspondingly, it is entirely impossible to treat the flow of a fluid confined within the pore space in any manner that could claim to be microscopically exact. This seems to preclude for ever the understanding of such things as Darcy's law from a microscopic standpoint.

A way out of the above difficulties is by representing an actual porous medium by something that the human brain can encompass. One therefore makes gross simplifications in a porous medium so as to enable one to formulate the boundary conditions and to integrate the basic Navier-Stokes equations. Such simplified versions of porous media are called models (cf. Ref. 36).

The simplest model consists of a bundle of parallel capillaries of circular cross section, all with the same diameter. It is easy to see that Darcy's law follows immediately for such a model, but unfortunately there are several features in it which are not satisfactory. Thus one notices that it gives a permeability in one direction only. All capillaries being parallel, there can be no flow orthogonal to the capillaries. The first modification of the model would therefore have to consist of putting one-third of the capillaries in each of the three spatial directions. In this manner, one obtains flow in any spatial direction, and a relationship between porosity and permeability can be deduced. One can express this relationship in terms of the internal surface area of the model, which is then called the "Kozeny-Equation." Unfortunately, this Kozeny-Equation holds only for the model and is not correct for the actual media without the addition of undetermined factors.

It appears that one of the main difficulties is that the diameters of the capillaries in the model are all identical—in some way equal to an "average" pore diameter in an actual porous medium. However, one would like to introduce a distribution function giving the fraction of pore space which has a pore diameter greater than a given value. It is therefore necessary to modify the model of parallel capillaries by trying

to replace the average pore diameter by some quantity which is clearly defined in terms of a pore-size distribution function. Thus, one can construct a model where all the capillaries permitting flow in a given direction are parallel to that direction, but varying in pore diameter, leading from one face of the porous plug through to the other. Such models are called "parallel-type models." The pore-size distribution of the model and an actual medium are made identical. Upon introducing such a model, it is seen that the relationship between porosity and permeability deduced from it is almost identical to that obtained from the first model discussed; notably, one again obtains the Kozeny-Equation which, as stated above, is not applicable to an actual medium without the introduction of undetermined factors.

A serious drawback of the parallel-type models is that all the pores are supposed to go from one face of a porous medium right through to the other. This is evidently a picture far remote from what is happening in actuality.

The opposite extreme picture would be obtained by assuming that the pore space is serially lined up, so that each particle of fluid would have to enter at one pinhole at one side of a porous medium and travel through very tortuous channels through all the pores and then emerge at one only pinhole at the other face of the medium. Obviously, this picture is just as unreal as a parallel-type model and a realistic model lies somewhere in between the extremes. We shall refer to such models as "serial-type models," as capillaries of different pore diameter are put together in series one after another.

One can now deduce similar porosity-permeability relationships from serial-type models as was done from the earlier types. One of the main features of the serial-type models is the appearance of a "tortuosity," which no parallel-type model can furnish. With such an additional parameter, there is no doubt that the model will fit any porous medium—simply by adjusting the tortuosity correctly. Another salient feature of serial-type models is that they give a formula for high-pressure flow—namely, if the nonlinearity occurring in the capillaries under such conditions is taken into account.

Reference has been made on several occasions to the Kozeny Equation. Kozeny (37) deduced his equation using a reasoning which does not refer openly to capillaric models. Thus it is usually held that Kozeny's treatment makes use of substantially fewer assumptions than does the construction of capillaric models. The final Kozeny equation involves only concepts of internal surfaces and such like, and does not make any specific reference to pore-size distribution.

A proper inspection of the Kozeny treatment, however, shows that it is based upon a two-dimensional analysis of the cross section of the porous medium. The treatment of Kozeny is therefore, for all practical purposes, equivalent to a model of parallel capillaries.

A different type of model has been suggested by Emersleben (38) and by Iberall (39). It may be noted that, in the models discussed above, the porous medium has been visualized essentially as a piece of solid material with holes in it. Emersleben and Iberall took the opposite view in that they visualized the porous medium as fluid-filled space with a few obstacles in it. The drag exercised by all the obstacles upon the fluid, then, represents the resistance of the medium to flow. It turns out that this type of model describes satisfactorily the flow through highly porous media, such as an agglomeration of fibers.

In spite of a partial success with the explanation of the empirical flow laws, the above models must be termed unsatisfactory upon general grounds. Although these models have been more or less useful to explain the permeability of a porous medium, it appears as a poor procedure indeed to represent a thing as disordered as a porous medium by well-ordered capillaric models. True, serial-type models are able to give a satisfactory relationship between porosity and permeability. It must be borne in mind, however, that this is really no great achievement, for all one was doing was making the models sufficiently complicated, proceeding from straight parallel capillaries, so as to introduce a sufficient number of parameters which will make them fit any arbitrary medium. The proper modification of the above models, therefore, seems to be the recourse to statistical mechanics (see Ref. 40).

Statistical mechanics is a device which has been invented to circumvent the ignorance of the human mind with regard to certain processes. It was first used in connection with the kinetic theory of gases where it was impossible to follow the path of each molecule that is contained in the gas under consideration.

The general scheme that is useful for the description of flow through porous media is that devised by Gibbs.

Let us recapitulate the basic system devised by Gibbs to cope with our fundamental ignorance about the insides of a process, and exemplify it on a porous medium.

A particle that progresses through a porous medium follows an exactly predetermined path—prescribed by the Navier-Stokes equations and the boundary conditions. The only difficulty is that we do not know these boundary conditions. One can circumvent this difficulty by considering, instead of the one specific system that is in question, a whole ensemble of systems (i.e., in our case, porous media) which are, in the face of our ignorance about their insides, "macroscopically identical." Furthermore Gibbs assumed that a particle in a specific system (porous medium) will, in time, encounter all the conditions that are present in the many systems (porous media) representing the ensemble. In other words, he assumed that one can interchange time-averages and ensemble averages. This is called the ergodic hypothesis. It enables one to treat the path of a particle through a system (porous medium) by statistics, although the latter is, in fact, entirely pre-determined by the boundary conditions.

The first step in any statistical theory is, therefore, to choose an ensemble representing all the porous media that we wish to call—in our ignorance—"identical."

The next step is to choose the type of statistics to be employed—or, in other words, the field of *a priori* probabilities within the chosen ensemble. In virtue of the ergodic hypothesis, this can also be expressed by saying that one has to choose "what happens in each time time-step." For instance, if one assumes a random distribution of residence times, then, in virtue of the Central Limit Theorem, one will always arrive at a Gaussian distribution for the probability, ψ, of a specific particle being at the position x at time t where $\bar{x}$ is the average position of the particle. One obtains

$$\psi(x,t) = (4\pi D t)^{-1/2} \exp\left[-(x-\bar{x})^2/(4Dt)\right] \qquad [8]$$

This automatically implies that the function ψ, expressed in "mean" co-ordinates x' (i.e., co-ordinates in which there is no mean flow) is subject to a diffusivity equation

$$\frac{\partial \psi}{\partial t} = D\Delta\psi. \qquad [9]$$

The final assumption that has to be made in any statistical model is with regard to what happens in each small time-step. This is called "microdynamics." The microdynamical assumption specifies whether we want to consider laminar flow, turbulent flow, Knudsen (molecular) flow, or something else in each microscopic flow channel. The microdynamical assumption does not change the fundamental diffusivity equation (the latter is an outcome of the type of statistics that has been chosen), but gives a means of correlating the constants occurring therein with other properties of the porous medium.

The various models discussed above give, if not a completely satisfactory explanation, at least an intuitive one of the various phenomena that are observed if fluids are flowing through porous media.

6. DISPLACEMENT PROCESSES

Of particular interest, in connection with engineering applications, is the theory of *displacement processes* in porous media. Such displacement processes are of importance in the production of oil from underground strata, in the exploitation of groundwater resources, and in the operation of towers in chemical engineering.

It turns out that the displacement occurs in an entirely different fashion depending on whether the two fluids involved are miscible or not. However, it is possible to set up an elementary theory which is the same for miscible and immiscible fluids. In this elementary theory, no mixing between the two flowing phases is assumed to take place at all. The two phases are confined to domains whose extent changes with time. Each fluid moves within its own domain according to Darcy's law. This view of a displacement process has been put to good use by Muskat (1) after whom it is called the "Muskat Model." If the permeability-viscosity ratios are the same in the two fluids, one can simply use the solutions of Darcy's law for single-phase flow and trace the movement of the boundary. If the permeability-viscosity ratios are not the same, a floating boundary problem has to be solved. Muskat discussed some such cases, but the greatest effort in this direction has been made by various Russian investigators, abstracts of whose work have appeared continuously during the past few years in *Applied Mechanics Reviews* (41-45, among others). An investigation along these lines has also been published by Aronofsky (46) in which the recovery of oil in various displacement patterns was calculated for different viscosity ratios.

The "elementary" displacement theory discussed above also shows that *instability* may occur if a fluid is displaced from a porous medium by a less viscous one. In this case, *fingering* is liable to occur which means that the displacement front becomes unstable: Fingers form which shoot at relatively great speed through the porous medium. A criterion for the onset of fingers (including capillary-pressure and gravity terms which can be introduced *a posteriori* in the "elementary" theory) has been given by Chuoke *et al* (47); the growth of incipient fingers in terms of the velocity inhomogeneities has been given by the writer (48). The calculations are fairly involved and the reader is referred to the original papers for the details. The fingering phenomenon can also be studied by the means of analog models (using a bulk-viscous fluid between two parallel plates), which has been done by Saffman and Taylor (49).

After the foregoing discussion of "elementary" displacement theory, we now turn our attention to theories where the simultaneous flow of different fluids at any one point in the porous medium is truly accounted for. This introduces a further variable which describes the fraction of the total amount of fluid that consists of the one phase. In immiscible displacement, this variable is usually called the "saturation" s; in miscible displacement, it is usually called "concentration" c.

Turning first to *immiscible* displacement, we note that a theory can be obtained by writing down Darcy's law for each phase, introducing a "relative permeability" k_i (as a fraction of total permeability k) to that phase (i) which is assumed to be a function of saturation only. This, in conjunction with usual continuity equations and equations of state for both flowing phases, leads to a complete system of differential equations which describes the displacement processes. Unfortunately, it is nonlinear and solutions have only been obtained for the one-dimensional case. Of these, the most famous is the Buckley-Leverett (50) solution for the displacement in a linear system, omitting capillary pressure and gravity terms. In this case, one can eliminate all unknowns except the saturation of one fluid, for which a nonlinear first-order partial differential equation is obtained. The latter is amenable to treatment by the method of characteristics. It turns out that the equation is similar to those encountered in gas dynamics: One has the possibility of occurrence of a "shock" front (i.e. a finite jump of saturation) which proceeds across the porous medium at a calculable speed.

The physical significance of the concept of "relative permeability" has also been studied. A series of models has been proposed from which a variety of relationships has been deduced. The Kozeny theory has also been extended to immiscible displacement; all this with only modest success (See 4).

Finally, turning to *miscible* displacement, we note that phenomena are encountered which are entirely different from those occurring in immiscible displacement. There are no shock fronts; the predominant effect (as long as no fingering occurs) is a progressive blurring of the interface between the two fluids which has been called "dispersion." It is described by a diffusivity equation referring to a moving coordinate system connected with the overall motion of the mixture of the two fluids. Solutions have been obtained (51) for the linear case which check very well with experimental evidence (52). Various theories have been advanced (53) to give a physical explanation for the observed diffusivity constants. It seems that the effect is not at all caused by molecular diffusion, but rather by mechanical dispersion of the two fluids caused by the interconnections of the flow channels. This shows that the statistical models discussed in Sec. 5 have a direct application to miscible displacement theory. However, the question as to which is the best model to be used is still open.

BIBLIOGRAPHY

1 Muskat, M., The flow of homogeneous fluids through porous media; New York, McGraw-Hill Book Co., 1937.

2 Leibenzon, L. S., Dvizhenie prirodnykh zhidkostei i gazov v poristoi srede; Moskva, Gos. Izdat-vo Tekh.-Teoret. Lit., 1947.

3 Polubarinova-Kochina, P. Ya., Teoriya dvizheniya gruntovykh vod; Moskva, Gos. Izdat-vo Tekh.-Teoret. Lit., 1952; AMR **8** (1955), Rev. 1220.

4 Scheidegger, A. E., The physics of flow through porous media; New York, Macmillan Co. (Toronto: Univ. of Toronto Press), 1957; AMR **12**(1959), Rev. 2149.

5 Carman, P. C., The flow of gases through porous media; New York, Academic Press, 1956; AMR **12**(1959), Rev. 5309.

6 Muskat, M., Physical principles of oil production; New York, McGraw-Hill Book Co., 1949.

7 Lykov, A. V., Yavleniya perenosa v kapillyarno-poristykh telakh. Moskva: Gos. Izdat-vo Tekh.-Teoret. Lit., 1954. German translation by K. Steffes (under the title: Transporterscheinungen in kapillarporösen Körpern; Berlin, Akademie-Verlag, 1958).

8 Todd, D. K., Ground water hydrology; New York, John Wiley & Sons, 1959.

9 Darcy, H., Les fontaines publiques de la ville de Dijon; Paris, V. Dalmont, 1856.

10 Hubbert, M. K., *J. Geol.* **48**, p. 785, 1940.

11 Nutting, P. G., *Bull. Amer. Assoc. Petrol. Geol.* **14**, p. 1337, 1930.

12 Ferrandon, J., *Génie Civ.* **125**, p. 24, 1948.

13 Biot, M. A., *J. Appl. Phys.* **12**, p. 155, 1941.

14 Biot, M. A., *J. Appl. Phys.* **27**, p. 459, 1956; AMR **10**(1957), Rev. 1105.

15 Florin, V. A., *Dokladi. Akad. Nauk SSSR* **59**, p. 219, 1948.

16 Barenblatt, G. I., and Krylov, A. I., *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 2, p. 5, 1955; AMR **10**(1957), Rev. 2712.

17 Scheidegger, A. E., *Canad. J. Phys.* **37**, p.276, 1959.
18 Aronofsky, J. S., and Jenkins, R., Proc. 1st. Nat. Congr. Appl. Mech., 1952; p.763.
19 Aronofsky, J. S., and Jenkins, R., *Trans. Amer. Inst. Min. Met. Engrs.* **201**, p.149, 1954.
20 Aronofsky, J. S., and Ferris, O. O., *J. Appl. Phys.* **25**, p.1289, 1954.
21 Aronofsky, J. S., and Porter, J. D., *J. Appl. Mech.* **23**, p.128, 1956.
22 Carslaw, H. S., and Jaeger, J. C., Conduction of heat in solids, second ed.; Oxford, Clarendon Press, 1959; AMR **12**(1959); Rev. 6280.
23 Nielsen, R. F., *World Oil* **132**, no. 6, p.188, 1951.
24 Plain, G. J., and Morrison, H. L., *Amer. J. Phys.* **22**, p.143, 1954; AMR **7**(1954), Rev. 2705.
25 Forchheimer, P., *Z. Ver. Deuts. Ing.* **45**, p.1782, 1901.
26 Romita, P. L., *Ricer. Scient.* **21**, p.1978, 1951.
27 Irmay, S., *Trans. Amer. Geophys. Un.* **39**, p.702, 1958; AMR **12**(1959), Rev. 546.
28 Engelund, F., *Trans. Danish Acad. Tech. Sci.* no. 3, 1953; AMR **7**(1954), Rev. 2704.
29 Schaaf, S. A., *Appl. Mech. Rev.* **9**, p. 413, 1956.
30 Collins, R. E., and Crawford, P. B., *Trans. Amer. Inst. Min. Met. Engrs.* **198**, p.339, 1953.
31 Aronofsky, J. S., *J. Appl. Phys.* **25**, p.48, 1954.
32 Von Engelhardt, W., and Tunn, W. L. M., *Heidelberger Beitr. Min. Pet.* **2**, p.12, 1954.
33 Michaels, A. S., and Lin, C. S., *Indust. Engng. Chem.* **47**, p.1249, 1955.
34 Zhavoronkov, N. M., et al, *Zh. Fiz. Khim.* **23**, p.342, 1949.
35 Schwartz, C. E., Flow distribution in packed columns; Ph. D. thesis, Purdue Univ.
36 Scheidegger, A. E., *Producers Monthly* **17**, no. 10, p.17, 1953.
37 Kozeny, J., *Sitz. Wiener Akad. Wiss. Abt. IIa*, **136**, p.271, 1927.
38 Emersleben, O., *Physikal. Z.* **26**, p.601, 1925.
39 Iberall, A. S., *J. Res. Nat. Bur. Stand.* **45**, p.398, 1950.
40 Scheidegger, A. E., *J. Appl. Phys.* **25**, p.994, 1954; AMR **8**(1955), Rev. 2897.
41 Guseinov, G. P., *Dokladi. Akad. Nauk Azerb SSR* **10**, no. 2, 1954.
42 Guseinov, G. P., *Trudi Azerb. N.-I. In-ta po dobyche nefti*, no. 3, p.138, 1956; AMR **12**(1959), Rev. 2704.
43 Salekhov, G. S., *Izv. Kaz. Fil. Akad. Nauk SSSR, Ser. Fiz. Mat. Tekh. Nauk* no. 5, p.3, 1954; AMR **11**(1958), Rev. 3836.
44 Salekhov, G. S., *Dokladi Akad. Nauk SSSR* **101**, p.809, 1955; AMR **10**(1957), Rev. 336.
45 Pilatovskii, V. P., *Dokladi Akad. Nauk SSSR* **110**, p.742, 1956; AMR **12**(1959), Rev. 1086.
46 Aronofsky, J. S., *Trans. Amer. Inst. Min. Met. Engrs.* **216**, T.P. 8073, 1959.
47 Chuoke, R. L., et al, *Trans. Amer. Inst. Min. Met. Engrs.* **216**, T.P. 8073, 1959.
48 Scheidegger, A. E., *Phyics of Fluids* **3**, no 1, 1960 (in press).
49 Saffman, P. G., and Taylor, G. I., *Proc. Roy. Soc. Lond.* (A) **245**, p.312; AMR **12**(1959), Rev. 547.
50 Buckley, S. E., and Leverett, M. C., *Trans. Amer. Inst. Min. Met. Engrs.* **146**, p. 107, 1942.
51 Scheidegger, A. E., *Trans. Amer. Geophys. Un.* **39**, p.92, 1958; AMR **12**(1959), Rev. 3673.
52 Scheidegger, A. E., Trans. 2nd Conf. on Fluid Flow Through Porous Media, Univ. Oklahoma, Norman, 1959.
53 Scheidegger, A. E., *C. R. Assn. Gén. Toronto, Assoc. Intern. Hydrologie Scient.* (U.G.G.I.) **2**, p.236, 1957.

Analytical Methods in Applied Mechanics

(See also Revs. 2131, 2136, 2137, 2144, 2145, 2146, 2192, 2197, 2207, 2223, 2296, 2303, 2318, 2319, 2344, 2353, 2357, 2480, 2487, 2499, 2551, 2604, 2605, 2606, 2626)

Book—2117. Bendat, J. S., Principles and applications of random noise theory, New York, John Wiley & Sons, Inc., 1958, xxi + 431 pp. $11.

Author attempts to provide a directly applicable guide to the use of statistical methods in the study and design of communications systems. Mathematical background [Chapters 1–3] is provided on the intuitive or "motivational" level without resort to development of (mathematically) technical details. Thereafter study is made of applications in fields of importance. Chapter titles with reviewer's summaries in parentheses are: 1. Random processes, engineering systems, correlation functions (Physical interpretations, elementary mathematics.) 2. Power spectra and relationships (Applied ergodic theory.) 3. Probability theory, random noise analysis (Distributions of expected values of important random variables, e.g., number of zero-crossings, number of maxima, for random processes.) 4. Optimum linear prediction and filtering (Wiener's methods brought to bear on explicit problems.) 5. Exponential-cosine autocorrelation functions (Discussion of a wide class of examples falling under the title subject.) 6. Analog computer techniques (Diagnosis of error behavior through simulation of systems on analog computers.) 7. Statistical errors in autocorrelation measurements (Use of short record formulas for autocorrelation functions and the errors associated with such approximations.) 8. Envelope detection and correlations of random noise (Use of detectors to bring study of correlation problems to the frequency range of the envelopes of the noise rather than to the frequencies of the noise itself.) 9. Optimum time-variable filters (Realization of filters conforming to optimality of prediction. Preceded by solution of Wiener-Hopf equation in special cases.) 10. The zero-crossing problem (Self-explanatory.) B. Gelbaum, USA

Book—2118. Smith, D. E., A source book in mathematics, Vol. 1: The field of number, the field of algebra; Vol. 2: The field of geometry, the field of probability, the field of the calculus, functions, quarternions, New York, Dover Publications, Inc., 1959, xiii + 701 pp. $1.85; xiii + 701 pp. $1.85. (Paperbound)

These present editions, first published in 1959, are unabridged and unaltered republications of the first edition, published in 1929 as a one-volume work. Ed.

Book—2119. Methodology of statistics on research and development, (NSF 59-36), Washington 25, D. C., Superintendent of Documents, U. S. Government Printing Office, 1959, 132 pp. $1.25. (Paperbound)

2120. Devianin, E. A., On the properties of equations of the first approximation in the method of averaging, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22**, 5, 1010–1019, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Using averaging method devised by Bulgarov, author shows that with few assumptions the averaged equations of a gausilinear vibrating system can be reduced to a special form which allows the establishment of certain properties very useful for a number of specific problems. Such properties have been investigated and studied in this paper. M. M. Stanisic, USA

2121. Mandel, J., The theory of extreme values, *ASTM Bull.* no. 236, 29–30, Feb. 1959.

2122. Wilkinson, J. H., Stability of the reduction of a matrix to almost triangular and triangular forms by elementary similarity transformations, *J. Assn. Comput. Machy.* **6**, 3, 336–359, July 1959.

Two methods are described for reduction of matrices to almost triangular form, and a further method for reduction of almost trian-

gular matrices to triangular form. ("Almost triangular" means $a_{jk} = 0$ provided $j \geq k + 2$). Emphasis is laid on numerical stability, and details are given for computation in fixed-point arithmetic with electronic computer in order to minimize rounding errors. It is shown that the latter method suffers from numerical instability which may render it unfit for finding the eigenvectors; but a method to overcome this difficulty is developed, giving satisfactory results on DEUCE computer. All methods described are claimed to be far superior to corresponding methods proposed earlier by W. Givens ["Computation of plane unitary rotations transforming a general matrix to triangular form," *J. Soc. Indust. Appl. Math.* **6**, 26–50, 1958]. K. Eggers, Germany

2123. Rodden, W. P., Further remarks on matrix interpolation of flexibility influence coefficients, *J. Aero/Space Sci.* **26**, 11, 760–761 (Readers' Forum), Nov. 1959.

2124. Golomb, M., Expansion and boundedness theorems for solutions of linear differential systems with periodic or almost periodic coefficients, *Arch. Rational Mech. Anal.* **2**, 3, 284–308, Dec. 1958.

Systems of the form

$$i^{-1} K w_x = A w + \lambda B(z) w \qquad [1.1]$$

are discussed, in which the independent variable may be real or complex and the elements of the matrix $B(z)$ are periodic, almost periodic, or have general nonharmonic Fourier expansions. Matrices K and A are constant and λ is a complex parameter. Systems of second order of the form

$$u_{\mu_{xx}} + \sigma_\mu^2 u_\mu + 2\lambda \sum_{\nu=1}^{m} b_{\mu\nu}(z) u_\nu = 0, \quad \mu = 1, 2, \ldots, m \qquad [3.1]$$

are shown to be equivalent, under certain conditions, to [1.1]. Equation [3.1] is specialized to Hill's equation and to Mathieu's equation, and a new expansion of $ce_n(z, \lambda)$ and $se_n(z, \lambda)$ are displayed. Convergence of the solution to [1.1] is shown for sufficiently small λ and a general criterion for boundedness and unboundedness is established for all or some of the solutions on the positive real line.

One advantage claimed for the method outlined is that it leads to less formidable calculations than other existing methods.

W. C. Orthwein, USA

2125. Buckens, F., On families of eigenvalue hypersurfaces (in German), *Öst. Ing.-Arch.* **12**, 1/2, 82–93, Nov. 1958.

Author considers an ordinary linear homogeneous self-adjoint differential equation containing several linear parameters $\lambda_i (i = 1, 2, \ldots, r)$ with given boundary conditions. Eigenfunctions of such a differential equation exist only if characteristic relations are satisfied between these parameters. The families of eigenvalues ("Eigenwertscharen") form characteristic hypersurfaces in the λ-space. Using their properties the eigenvalues of the differential equation can be evaluated approximately. Author considers also the limit case $r = \infty$ (Hilbert-space) and, finally, gives some examples.

From author's summary by J. Lense, Germany

Book—2126. Goursat, E., A course in mathematical analysis, Vol. 1, Applications to geometry, expansion in series, definite integrals, derivatives and differentials, New York, Dover Publications, Inc., 1959, viii + 548 pp. $2.25. (Paperbound)

Book is an unabridged and unaltered republication of the translation from the French by E. R. Hedrick in 1904. Ed.

Book—2127. Goursat, E., A course in mathematical analysis, Vol. 2, Part 1, Functions of a complex variable; Part 2, Differential equations, New York, Dover Publications, Inc., 1959, x + 259 pp. $1.65; viii + 300 pp. $1.65. (Paperbound)

Part 1 is an unabridged and unaltered republication of the E. R. Hedrick and O. Dunkel translation of the second French edition in 1916.

Part 2 is an unabridged and unaltered republication of the Hedrick-Dunkel translation in 1917. Ed.

Book—2128. Pierpont, J., Functions of a complex variable, New York, Dover Publications, Inc., 1959, xiv + 583 pp. $2.45. (Paperbound)

Book is an unabridged and unaltered republication of the first edition, 1914. Ed.

Book—2129. Pierpont, J., Lectures on the theory of functions of real variables, Vols. 1 and 2, New York, Dover Publications, Inc., 1959, xii + 560 pp. $2.45; xiii + 645 pp. $2.45. (Paperbound)

Books are unabridged and unaltered republications of the last editions, Vol. 1 (1905), Vol. 2 (1912). Ed.

Book—2130. Coolidge, J. L., A treatise on algebraic plane curves, New York, Dover Publications, Inc., 1959, xxiv + 513 pp. $2.45. (Paperbound)

This is an unabridged and unaltered republication of the first edition, 1931. Ed.

Computing Methods and Computers

(See also Revs. 2122, 2123, 2149, 2150, 2230, 2308, 2356, 2368, 2384, 2491, 2501, 2585, 2604)

2131. Schroder, J., Error estimations in ordinary and partial differential equations (in German), *Arch. Rational Mech. Anal.* **2**, 4, 367–392, Jan. 1959.

Example 1: $-u_{xx} = 3xu^2 - u^3$, $u(0) = \frac{1}{2}$, $u(1) = 1$ is treated as follows. First, using the difference equation approximation with $\Delta x = 1/8$, one gets a solution which is then approximated (with the method of least squares) by $u_0(x) = \frac{1}{2}(1 + x) + x(1 - x)(a + bx)$, with $a = 0.097858$, $b = 0.372027$. Substituting this $u_0(x)$ for u in the right-hand member of the differential equation, another approximate solution $u_1(x) = \frac{1}{2}(1 + x) + x(1 - x)(\alpha_0 + \alpha_1 x + \ldots + \alpha_9 x^9)$ is obtained. Then a function $\sigma_1(x)$ is found such that $|u_1(x) - u_0(x)| \leq \sigma_1(x)$. $\sigma_1(x) = 0.0367\, x(1 - x)$ is one of such functions. Now, the function $f = 3u$ is a majorant to the right-hand member $3xu^2 - u^3$ in a certain sense, and it leads to the conditions $-\sigma_{xx} \geq 3\sigma + 3\sigma_1$, $\sigma(0) = \sigma(1) = 0$, which may be used to determine a function $\sigma(x)$ dominating the error $|u^*(x) - u_1(x)|$, where $u^*(x)$ denotes the true solution.

Similarly treated are Example 2: $-(u_{xx} + u_{yy}) = \alpha + x^3 u^3$ for $0 \leq \sqrt{x^2 + y^2} < 1$, $u = 0$ for $\sqrt{x^2 + y^2} = 1$, with a positive constant α; and Example 3: $u_x = x^2 + u^2$ for $0 \leq x \leq \alpha$, $u(0) = 1$.

Methods are based on theorems given and proved in the paper in a rigorous form.

Reviewer agrees with author in that combined use of functional-analytic methods and electronic computers in numerical analysis will be fruitful. S. Moriguti, Japan

2132. Greenspan, D., Note on difference equation approximations of Laplace's equation, *J. Franklin Inst.* **268**, 1, 46–52, July 1959.

If for a Dirichlet problem the Laplace equation is replaced by a difference equation and the region by a grid with sizes h and d in x and y direction respectively, then a fifth approximation is set up, which is shown to be a best analog if $h \neq d$ in the following sense that (a) no sixth-order allowable analog exists, (b) no other allowable, fifth-order analog can exist which differs from it except for a multiplicative constant. A. Van Heemert, Holland

2133. Kluger, P., and Farrel, E. C., Digital computer analysis of transients in liquid rocket engines, *Jet Propulsion* **28,** 12, 804–809, Dec. 1958.

A digital computer program for engine transient study has been developed to obtain an evaluation of pressure surges in the propellant system during startup and shutdown. This technique is intended to supplement and eventually replace analog computer start and shutdown transient analysis which does not provide realistic simulation of propellant lines and combustion dead times. The mathematical model used for propellant line representation was based on the water-hammer theory as originally developed by Allievi, i.e.; hydraulic oscillations appear as pressure surges caused by the conversion of kinetic to potential energy, where the kinetic energy changes are a result of system impedance changes taking place during engine start or shutdown. Line equations and component transfer functions have been programmed in a general manner, allowing routine parameter changes to be executed without the need of major reprogramming. The analysis determined the values of instantaneous propellant flow and transient pressures at points of interest in the system for successive time intervals.

From authors' summary

2134. Dunsmore, C. L., Computer analogs for common nonlinearities, *Control Engng.* **6,** 10, 109–111 (Data File), Oct. 1959.

Analog computer circuits for four basic nonlinearities are presented, with some practical hints for their use, plus five more complex nonlinearities that can be simulated as combinations of the basic ones. The last circuit (for analoging stiction) gives a clue to why large analog computers are so often needed to simulate even relatively simple engineering problems.

From author's summary

Analogies

(See Revs. 2180, 2190, 2192, 2208, 2306, 2433, 2441, 2585, 2659)

Kinematics, Rigid Dynamics and Oscillations

(See also Revs. 2314, 2318, 2319, 2407, 2551, 2605, 2610)

2135. Geronimus, Ya. L., The properties of the Hamilton center of some vector systems (in Russian), *Trudi Kharkovsk. Aviats. In-ta* no. 17, 11–21, 1957; *Ref. Zh. Mekh,* no. 1, 1959, Rev. 43.

Paper gives information on a number of new facts concerning the properties of the Hamiltonian center of some special systems of fixed physical vectors. Thus, for instance, for a system of vectors disposed in planes perpendicular to some straight line, proof is advanced of the invariant nature of the Hamilton center and of the parameter of the screw of the given system as regards the group of rotations of the vectors in their planes; for this proof use is made of the technique of the theory of Kvatemionov. The author's results might find an applied value as well, for instance, in investigating the properties of the Hamilton system on vectors $m(d^n r/dt^n)$ during the rotation of the body around an axis and during plane-parallel motion; the role of the Hamilton center is explained in resolving the forces of inertia of the points of a symmetrical gyroscope during regular precession, and so forth.

V. V. Dobrontavov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2136. Hovanessian, S. A., Analysis of a nonlinear mechanical system with three degrees of freedom, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 546–548, Dec. 1959.

The system consists of three masses connected by means of springs. The restoring forces R are cubic functions of the deviations x: $R = kx \pm ex^3$. A periodical external force $F_0 \cos wt$ is assumed to be acting upon the last mass. The equations of motion contain cubic terms. Author applies Duffing's method setting $x_i = A_i \cos wt$ as a first approximation. Neglecting the $\cos 3wt$ – terms, he gets a system of cubic equations for the amplitudes A_i. In the special case of two equal masses he outlines a graphical method of solution. It is illustrated by two examples. The question of stability is not dealt with.

W. Hahn, India

2137. Kiuchi, A., On the vibration characteristics of an elastically supported mechanical system with a non-uniform shaft having masses on it, *Bull. JSME* **2,** 6, 318–323, May 1959.

Vibration equations are given in matrix form for a stepped shaft with concentrated masses and elastic supports. Numerical example shows calculation for critical speed of a mixer with close check of experiment. Natural frequency equation for a floating or flying body is obtained. Theory may be applied to find critical speed of a jet engine. Paper is condensed and reader may find need to consult earlier papers of same author given in references.

R. B. McCalley, Jr., USA

2138. Proskuriakov, A. P., On ways of introducing a small parameter into equations of nonlinear vibrations, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 5, 1005–1009, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The problem of the convergence of the series which represents the periodic solution for a nonlinear vibrating system using perturbation technique in various ways has been studied and examined. It has been shown that the periodic solution of the system can be obtained if the solution of the generating system forms a family of solutions dependent on the arbitrary parameter. Such periodic solutions converge always with a large radius of convergence. The paper shows quite a few interesting phenomena—logical occurence in the theory of nonlinear vibrations. Few examples are presented.

M. M. Stanisic, USA

2139. Bogusz, W., The stability of motion of bars rotating with variable angular velocity (in Polish), *Rozprawy Inz.* **6,** 4, 549–555, 1958.

The rotating motion of a bar with small eccentric load and sinusoidal speed variation is analyzed. For oscillating speeds there exist, besides the critical static speed, dynamical critical speeds for which the motion ceases to be stable. Under the assumptions of this paper the instability conditions of the motion of the rotating bar do not depend on the amplitude of speed variation.

Z. Olesiak, Poland

2140. Kuzovkov, N. T., On the motion of a gyro-stabilized platform, mounted on double gimbals (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 94–97, July 1958.

General theory of a gyro-stabilized platform suspended on double gimbals by A. Y. Ishlinsky and G. W. Chechovich is referred to. The author analyzed small oscillations which take place in some critical positions of the platform. Equations of motion deduced show a definite relationship between the behavior of the discussed suspension and that of a suspension based on a regular gimbal.

M. G. Bekker, USA

Instrumentation and Automatic Control

(See also Revs. 2117, 2140, 2407, 2523, 2598, 2605, 2614)

2141. Batkov, A. M., The problem of synthesizing linear dynamic systems with variable parameters, *Automation and Remote Control* **19,** 1, 42–48, Jan. 1959. (Translation of *Avtomatika i*

Telemekhanika **19**, 1, 49–55, Jan. 1958 by Instrument Society of America, Pittsburgh, Pa.)

Author presents a method for determining the differential equation of a linear dynamic system with variable parameters when the impulse transient response is given. The transfer function of such a system depends not only on frequency but also on time. The proposed method is completely applicable to systems with constant parameters. The questions involved in determining the design corresponding to the equation are considered in several examples.

S. Z. Dushkes, USA

2142. Kreimerman, M. M., Determination of parameters for corrective devices in linear servosystems using given generalized parameters, *Automation and Remote Control* **19**, 2, 124–136, Jan. 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **19**, 2, 135–148, Feb. 1958 by Instrument Society of America, Pittsburgh, Pa.)

An analytical method is described for determination of parameters for correcting devices in a linear servosystem when the values of some of the generalized parameters of the system are given, such as the asymptotic crossover frequency, the phase margin of stability and the relative quality factor. A table of basic formulas for calculations is given, and examples of computations are carried out for series and parallel correcting devices and also for combinations of them.

From author's summary by C. B. Ludwig, USA

2143. Segalin, V. G., An analytical formulation of the synthesis problem of corrective devices in linear servosystems, *Automation and Remote Control* **19**, 2, 137–155, Jan. 1959. (Translation of *Avtomatika i Telemekhanika, USSR*, **19**, 2, 148–162, Feb. 1958 by Instrument Society of America, Pittsburgh, Pa.)

An analytical formulation of the generalized problem of synthesizing corrective devices in linear servosystems is proposed, and, on the basis of the initial synthesis equations which are derived, a method is worked out for determining the transfer functions of corrective devices for the most frequently encountered cases of correction. In conclusion, an example is given of a solution of the synthesis problem.

From author's summary by C. B. Ludwig, USA

2144. Boiarinov, V. S., and Leonov, N. N., On the theory of one-relay systems, *Automation and Remote Control* **19**, 2, 103–123, Jan. 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **19**, 2, 114–135, Feb. 1958 by Instrument Society of America, Pittsburgh, Pa.)

A thorough analysis is made of a single-relay control system whose open loop contains the relay followed by a second-order linear element, and whose feedback contains a first-order element. The former is assumed stable, the latter can be either stable or unstable. Two relay characteristics are studied, one with a hysteresis loop, the other with a dead zone. Positive and negative feedback is considered. The analysis is geometrical, using phase-plane and Koenig-LeMaire diagrams. An exhaustive classification is made of system configurations and parameter combinations by existence, number, and stability of limit cycles. This classification is claimed to be more complete than previous ones of the same system [AMR **2** (1949), Rev. 972; AMR **3** (1950), Rev. 1033; AMR **10** (1957), Rev. 2027].

R. F. Drenick, USA

2145. Lehnigk, S., Structural stability of simple linear proportional integrating or differentiating control loops with differentiating operation of at most second order (in German), Dtsch. Forschungsanstalt Luftfahrt, Ber. 81, 78 pp., 1957.

The loop is stable if all the roots of the polynomial $(g + h)$ have negative real parts. Here g is the numerator and h the denominator of the open-loop transfer function. Starting with a theorem of Ajzerman and Gantmacher [*Prikl. Mat. Mech.* **18**, 103–122, 1954; AMR **8** (1955), Rev. 2253] which gives bounds on the number of real and complex conjugate unstable roots g may have so that there exists a stable h of specified degree making $(g + h)$ stable, author presents an algebraic method for determining whether stability is possible by adjustment of gain parameters with h of degree 2 or less and arbitrary g. Partial results are given for higher degree h. Main value of method is in eliminating false starts on a new design.

C. M. Ablow, USA

2146. Dennis, F. L., and Linden, D. A., The derivation of pole-zero patterns by derivative adjustment, *J. Franklin Inst.* **268**, 4, 283–293, Oct. 1959.

Coefficients and pole-zero locations of a low-pass transfer function having n poles and m zeros may be determined by equating to zero at origin first r even derivations of amplitude and first $(n + m - 1 - r)$ even derivatives of phase. Procedure leads to set of simultaneous equations for coefficients. Closed form solutions are given for some special cases. Choice of r places emphasis on obtaining flatness of response or on phase linearity. Physical realizability is not guaranteed. Previous methods apply to transfer functions having poles only.

R. D. Milne, England

2147. Schmidt, S. F., and Harper, Eleanor V., Sampled-data techniques applied to a digital controller for an altitude autopilot, NASA Memo 4-14-59A, 71 pp., June 1959.

After a brief, almost irrelevant, discussion of Z transforms for pulses, this paper applies them to design an altitude autopilot in which the error is sampled and subsequently passed through a zero-order hold circuit.

Transforms for a controller designed to given stability, error, and finite settling time recipes are obtained for a given aircraft and two different sampling periods for step and ramp inputs.

The resulting designs were simulated on an analog computer and it was found that the experimental behavior of the system deviated from its theoretical design because of "extreme sensitivity of the system which makes it impossible to simulate ... even with highly accurate analog computing equipment." No other possible causes for this discrepancy (such as occurrence of error functions with zeros at sampling instants and the nature of linear circuits which produce zero errors in finite times) are mentioned. The simulation exhibited peak accelerations not prohibited by the design procedure, but which the paper states would not occur in an actual system because of nonlinearities. It is conjectured that "nonlinearities would also cause system instability."

Although the paper may have value for designers of autopilots, the reviewer believes it is of little general interest.

P. G. Kirmser, USA

2148. Bigelow, S. C., A digital-analog controller for sampled data systems, AFOSR TN 59-803 (Columbia Univ., Dept. Elec. Engng. TR T-36/B, CU-56-59-AF-677-EE), 47 pp., July 1959.

Report describes a practical digital controller for sampled data control systems, designed and constructed by the author.

The controller is a hybrid digital-analog computer programmed to solve the control equations. The machine input and output signals are voltage analogs in the range of from – 50 to + 50 volts. Arithmetic operations are performed using analog computer circuits, while storage is accomplished in digital storage registers. Analog-to-digital and digital-to-analog conversions are performed internally.

It is believed that this controller serves a twofold purpose: First to demonstrate the feasibility of applying the well-developed theory of sampled data control systems to real processes, and second to provide a useful tool for further study of such systems.

From author's summary

2149. Fleishman, B. A., Harmonic and subharmonic response of an on-off control system to sinusoidal inputs, AFOSR TN 59-360 (Rensselaer Polytech. Inst., Dept. Math. Rep. 24; ASTIA AD 213 670), 29 pp., May 1959.

Author derives periodic solutions of the second-order differential equation of a simple control system with proportional plus on-off control subjected to a sinusoidal input. Since between switch points the system is linear, solutions are a superposition of the sinusoidal response of the linear part of the equation, and a solution of the undisturbed equation, provided that the frequency of the latter is harmonically related to the frequency of the sinusoidal input.

Solutions of the undisturbed equation are derived by phase plane method, and those which have the required frequency are chosen to construct solutions of the complete differential equation. Restrictions on amplitude and frequency of the sinusoidal input for different possible solutions are derived.

P. DeWaard, Holland

2150. Stern, H., Measurement of angular acceleration in aircraft and missiles, *Aero/Space Engng.* **18,** 11, 48–50, 62, Nov. 1959.

Various techniques for measuring angular acceleration are compared. If real-time acceleration is not required, the measurement using a non-real-time numerical filtering and differentiation of angular velocity with a digital computer is superior to a real-time measurement using an analog accelerometer. This process is not extended successfully to the double differentiation of displacement angle in the aircraft and missile application.

V. B. Haas, Jr., USA

2151. Akhachinskii, V. V., and Mashirev, V. P., An automatic method for maintaining equality of temperature between two media, *Instruments and Experimental Techniques* no. 5, 688–690, July 1959. (Translation of *Pribory i Tekhnika Eksperimenta, USSR* no. 5, 94–97, Sept./Oct. 1958 by Instrument Society of America, Pittsburgh, Pa.)

An instrument is described for automatically maintaining two media at an equal temperature with accuracy up to 0.005° and for thermostatic control with accuracy up to 0.0005°.

From authors' summary

2152. Cairnie, A. B., and Pullar, J. D., Temperature controller based on measurement of rate-of-change of temperature, *J. Sci. Instrum.* **36,** 6, 249–252, June 1959.

The rate-of-change of temperature of water circulated from a 120-gal tank round the jackets of a direct calorimeter was required never to exceed 0.0005C/min. Measurement of the rate-of-change of temperature was provided by a gradient layer surrounding a metal block in the tank. A controller was designed to maintain the instantaneous rate-of-change of temperature below 0.0002C/min, except for a negligible fraction of the time. The mean rate-of-change of temperature is so low that temperature stability to within ±0.1C has been obtained for a fortnight. A temperature-controlled room and constant-voltage transformer are not required.

From authors' summary

2153. Hanel, R. A., Thermostatic temperature control of satellites and space vehicles, *ARS J.* **29,** 5, 358–361 (Tech. Notes), May 1959.

The temperature of satellites and space vehicles varies considerably with orbital conditions. To achieve greater reliability and efficiency in long-life instruments, an automatic temperature control is highly desirable; a radiation thermostat performing this function is discussed. The suggested method regulates temperature by adjusting the effective absorptivity and emissivity. Bimetallic strips automatically move a light shield which exposes surfaces with high and low absorptivity-emissivity ratios. No internal power source is needed. Calculations demonstrate the effectiveness of the radiation thermostat. The temperature of the satellite's instruments can be kept constant within a few degrees of the design value, regardless of orbital conditions, internally dissipated power and some erosion of skin coatings.

L. Lapidus, USA

2154. Vandeghen, A., Operation of boilers in the transient region (in French), *Rev. Univ. Mines* **15,** 6, 605–610, June 1959.

2155. Vandeghen, A., Thermal inertia of superheaters and reheaters (in French), *Rev. Univ. Mines* **15,** 6, 616–621, June 1959.

Tables, Charts, Dictionaries, etc.

Book—2156. Levens, A. S., Nomography, 2nd ed., New York, John Wiley & Sons, Inc., 1959, viii + 296 pp. $8.50.

A new and expanded edition contains theoretical backgrounds and practical methods of construction of nomograms (not "nomographs"), mostly in the form of alignment charts. Simplest forms —parallel scales, Z-type, intersecting scales, proportional charts, curvilinear scales, net charts, circular nomograms—are very well explained and illustrated by hundreds of examples taken from various fields of science and engineering. The use of determinants in the design and construction of nomograms concludes this splendid manual. In addition there are a summary of different type forms and two diagrams for subdivision of logarithmic and square-root scales.

Perfect edition is good for self-study and for colleges. It is well known that many schools have been able to acquire expensive electronic computers, but have not yet introduced nomography into their curricula. In this field we are regrettably far behind Europe, and particularly USSR. Reviewer wishes the best acceptance and recognition for this highly important book.

S. Kolupaila, USA

Elasticity

(See also Revs. 2190, 2193, 2197, 2198, 2202, 2210, 2211, 2219, 2223, 2224, 2225, 2236, 2241, 2248, 2249, 2275, 2276, 2322)

2157. Ershov, L. V., and Ivlev, D. D., On the dilation of thick-walled tubes subjected to internal pressure (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, 149–152, Aug. 1957.

Author seeks solutions to the case of a symmetrically loaded cylindrical tube, on which he imposes small elliptical deformations (both on the internal and external diameters). Using a generalized elastic stress-strain relation $\sigma_i = Ae_i^m$ where σ_i = stress, A is a constant, e_i corresponding deformation and m a dimensionless index. He obtains that value of internal pressure which enables the conventional stress boundary conditions to be satisfied. He particularizes the solution for $A = E$ and $m = 1$, the common Hookian case. He also considers the case of an idealized plastic zone within an elastic zone and derives a relation for the diameter at which the elastic-plastic boundary forms as a function of tube diameter ratios at the value of internal pressure stated above.

The mathematics is too concise to be readily followed without reference to previous work. No discussion is given of the assumptions made or, in fact, of the significance of the calculations.

A. Kennaway and J. R. A. Pearson, England

2158. Ignat'ev, M. O., Some applications of the method of reflections in a system of equations in the theory of elasticity (in Russian), *Nauchn. Zap. L'vovsk. In-ta* **44,** 60–70, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12983.

The regular portions of Green's matrix are separated out for a semispace and a circle and on the basis of these calculations conversions are obtained corresponding to solutions representing in themselves analogies of the known Kelvin conversion. Green's regular matrices are expressed through Somilian's fundamental matrix and its derivations. The possibility of this type of presentation emanates from Fredholm's known theorem regarding the presentation of the principal part of the solution of the system of equations of elasticity through the fundamental matrix and its derivatives. G. N. Savin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2159. Uflyand, Ya. S., The basic mixed problem in the theory of elasticity for a semispace with a rectilinear boundary dividing the boundary conditions (in Russian), *Nauchno-tekhn. Inform. Byul. Leningrad Politekhn. In-ta* no. 12, 22–27, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12973.

A method is given for the solution of the problem on the elastic equilibrium of an isotropic homogeneous semispace ($y \geq 0$), on a part of whose boundary ($x > 0$) transpositions are assigned (u, v, w) and on another part ($x > 0$) stresses are assigned (σ_y, τ_{yz}, τ_{yx}). It was shown that by using Fourier's integral conversion (on coordinate z) and Kontorovich-Lebedev's (on coordinate r) the system of mixed boundary conditions for Papkovich-Neiber's functions is transformed into a linear algebraical system in the space of representation (?). It is possible to obtain a presentation of the solution in the Fourier and Kontorovich-Lebedev integral in principle provided the system is calculated out and then a conversion carried out, during which process it is necessary to overcome some specific difficulty connected with the regulation of the sub-integral function. An example is given (not carried through to completion) of the calculation of the action of the concentrated normal force on the elastic semispace, part of whose boundary ($x > 0$) is rigidly clamped. There are many misprints in the formulas. (The theory of the integral conversion evolved by Kontorovich-Lebedev is described in adequate detail in the book: G. A. Grinberg, "Selected question relating to the mathematical theory of electrical and magnetic phenomena," Moscow-Leningrad, Izd-vo Akad. Nauk SSSR, 1948, §55–56.) N. A. Rostovtsev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2160. Caricato, G., On transformation of an elastic system that conserves isotropy, *R. C. Mat. Appl., Univ. Roma* (5) **17**, 3/4, 313–318, July/Dec. 1958.

Based on A. Signorini's work [*Ann. Mat. Pura Appl.* (4) **22**, p. 50, 1943], it is shown that in conformable displacements of an elastic system the isotropy is conserved.

B. R. Seth, India

2161. Golecki, J., On the assumption of incompressibility in plane problems of the theory of elasticity (in English), *Arch. Mech. Stos.* **11**, 3, 297–301, 1959.

A formulation of the object of the theory of elasticity is given in the case of plane and two-dimensional state of stress and strain or, in other words, in the case of transversal incompressibility. Suitable resolving functions are introduced, thus separating the given system of equations. In the particular case of plane strain and no mass forces the problem reduces to that of solving a harmonic and biharmonic equation. S. Kaliski, Poland

2162. Flitman, L. M., A boundary problem for an elastic semispace (in Russian), *Izv. Akad. Nauk SSSR, Ser. Geofiz.* no. 1, 105–106, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 766.

If in the dynamic equations in the theory of elasticity

$$(\lambda + \mu)\ \text{grad div}\ u + \mu \Delta u - \rho \frac{\partial^2 u}{\partial t^2} = 0$$

is inserted

$$u = \text{grad}\ \varphi + \text{rot}\ \psi$$

then the potentials φ and ψ are determined by separated wave equations; however, the boundary problems for them, generally speaking, are not divided. It is shown that in the case of an elastic semispace with a plane border and boundary conditions

$$\sigma_z = f_1(x, y, t), \qquad u = f_2(x, y, t), \qquad v = f_3(x, y, t) \quad (z = 0)$$

or

$$\tau_{zx} = f_1(x, y, t), \qquad \tau_{zy} = f_2(x, y, t), \qquad u = f_3(x, y, t) \quad (z = 0)$$

the boundary problems for the determination of potentials φ and ψ can be divided. V. K. Prokopov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2163. Sternberg, E., and Muki, R., Note on the expansion in powers of Poisson's ratio of solutions in elastostatics, Brown Univ., Div. Appl. Math. TR 6 (NR 064-431), 11 pp., Feb. 1959.

Highly theoretical paper has severely limited practical application. D. M. A. Leggett, England

2164. Balmer, H. A., Stress functions for plates of convex polygonal shape, *J. Aero/Space Sci.* **26**, 10, 675–676 (Readers' Forum), Oct. 1959.

2165. Miyao, K., Stresses in a circular disk with an eccentric circular hole fixed at its center and under a tangential force on the outer edge, *Bull. JSME* **2**, 6, 271–276, May 1959.

A straightforward application of general methods presented by Jeffery [*Phil. Trans. Roy. Soc. Lond.* **221**, p. 265, 1921]. Bipolar coordinates are used to solve the residual problem generated through the solution for a solid disk under the same loading. Numerical results are presented. R. A. Eubanks, USA

2166. Chattarji, P. P., and Dutt, S. B., On the stresses due to a nucleus in the form of a center of dilatation in an elastic infinite solid with rigid spherical inclusion, *J. Sci. Engng. Res., India* **3**, 1, 175–180, Jan. 1959.

An analysis is made of the stresses in an infinite elastic solid due to a nucleus in the form of a center of dilatation situated at a finite distance from a rigid spherical inclusion at the center of the system of spherical polar coordinates. Use is made of stress-function approach to an axisymmetric problem of elasticity. Numerical values are given for the stresses on the surface of the inclusion for a particular case. M. Holt, USA

2167. Sadowsky, M. A., and Zwicky, E. E., Jr., Stress distribution in a square tube with rounded corners loaded by internal pressure, *ASME Trans.* **81E** (*J. Appl. Mech.*) 2, 301–302 (Brief Notes), June 1959.

Using the methods of the theory of elasticity the numerical values of all stresses have been calculated. Regions of compressive hoop stresses and tensile radial stresses have been found. M. Sokolowski, Poland

Book—2168. Parkus, H., Transient thermal stresses [Instationare Warmespannungen], Wien, Springer-Verlag, 1959, v + 165 pp. $9.05.

The long-awaited companion volume to Melan and Parkus: "Temperature stresses due to steady-state temperature fields" [see AMR **7** (1954), Rev. 3829] was written by Professor Parkus alone. It covers clearly and comprehensively—although occa-

sionally too concisely—most of what had been published up to 1958 in this fast expanding field; it also includes hitherto unpublished material. Chapter headings are: (1) Some general theorems of thermoelasticity. (2) Heating and cooling processes. (3) Periodic temperature changes. (4) Moving heat sources. (5) Dynamic effects. (6) Thermal stresses in bodies made of viscoelastic materials. (7) Thermal stresses in bodies made of elasto-plastic materials.

Inertia effects are included in the general expressions derived in the first chapter; however, the inertia terms are retained in the fifth chapter only—the other five chapters deal with quasi-static problems. Most examples treated refer to infinite and semi-infinite bodies, spheres and circular cylinders, plates and disks.

By the nature of the task on hand, the mathematics used by the author is formidable, yet it should not be beyond research workers who have occasion to use the book; for those who require numerical information only, many of the results are presented in the form of clearly drawn graphs. A comprehensive bibliography further enhances the value of the book. Some minor criticisms: (1) because of its practical importance, Chapter 3 might have deserved a more detailed treatment than the five pages accorded to it; (2) many users would appreciate a list of symbols and an author index; (3) although the author hopes that the present book can be understood by those who have no knowledge of the Melan and Parkus book (see Preface), several references are made to this latter work without repeating the formulas or statements referred to.

G. Sved, Australia

2169. Nowinski, J., Note on a thermoelastic problem for a transversely isotropic hollow sphere embedded in an elastic medium, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 649–650, Dec. 1959.

This note generalizes the Galerkin problem to consider thermoelastic stresses in anisotropic bodies with an axis of symmetry. Stresses are obtained in a hollow sphere of two different transversely isotropic or Winkler material (i.e., isotropic in a plane perpendicular to the radius rector) layers when the sphere is subjected to an internal pressure and spherically symmetrical temperature field. The sphere is embedded in an elastic medium which is also considered to be transversely isotropic. In the limiting case, the form of the Winkler coefficient is indicated for an isotropic material by the last equation, which sould be numbered [13]. There is a typographical error in the first of equations [1]; the primes in the second term of right member should be omitted.

P. G. Bhuta, USA

2170. Biot, M. A., New thermomechanical reciprocity relations with application to thermal stress analysis, *J. Aero/Space Sci.* **26**, 7, 401–408, July 1959.

Based on the variational formulation of linear thermodynamics as developed previously by the author, thermomechanical reciprocity relations are discussed which lead to new methods of analysis of thermal stress. The results are applicable to stationary and transient temperatures in elastic and viscoelastic structures. The methods are entirely variational and do not require the evaluation of the temperature field. The concepts and procedures are illustrated on the simple problem of stationary thermal stresses in a thin circular cylinder.

From author's summary by G. Sestini, Italy

2171. Herrmann, G., Energy methods for the analysis of temperature distributions and thermal stresses in structures, AFOSR TN 59-327 (Columbia Univ., Dept. Civil Engng. & Engng. Mech., Inst. Flight Struct. Cu-4-59-AF-430-CE; ASTIA AD 213 675), 12 pp., May 1959.

Paper presents a "popular" account of variational principles in the field of heat conduction and thermoelasticity. Treatment is confined to one space dimension and forms a useful introduction to the writings of Biot, Reissner, the author and others in this field. The "definition" of b on p. 6 should be elucidated by means of equations [13].

W. S. Hemp, England

2172. Chao, H.-Y., Thermal stresses in shells of revolution of variable elastic properties, *Scientia Sinica* **8**, 4, 383–400, Apr. 1959.

Author assumes Young's modulus of elasticity to be a linear function of temperature and uses an iteration procedure starting from the solution for the constant modulus. The effect is demonstrated in an example of a long cylindrical shell clamped at one end subjected to a temperature distribution decreasing exponentially in the axial direction from a maximum at the clamped end. Considerable reduction in the hoop compression load and axial bending moment at the clamped end is obtained.

B. E. Gatewood, USA

2173. Piechocki, W., The state of stress in a circular disc due to the action of a nucleus of thermoelastic strain (in English), *Arch. Mech. Stos.* **11**, 3, 287–295, 1959.

To determine the stress in a circular region, due to nuclei of thermoelastic strain distributed in an arbitrary manner or an inclusion, it suffices to know the Green's function of the problem. Using the potential of thermoelastic strain and the Airy function, author determines that function and obtains solutions in certain particular cases.

M. Sokolowski, Poland

2174. Derski, W., Non-steady-state of thermal stresses in a layered elastic space with a spherical cavity (in English), *Arch. Mech. Stos.* **11**, 3, 303–316, 1959.

The displacement and stress distribution is obtained for an elastic space with a spherical cavity $a \leqslant r \leqslant b$ of which the surface $r = a$ is heated according to the law $T = T_0 \frac{t}{\tau}$. The solution method is based on the familiar equation for the temperature field and is done by means of superposition of stress and displacements obtained for the so-called thermoelastic potential and the compensating system. On the stresses and the displacements thus obtained the conditions of zero stresses at the edge $r = a$ are imposed as well as zero stresses and displacements at infinity and the continuity condition at the interface $r = b$. In the particular case of $a = b$, $\tau \to 0$, the problem becomes identical with that considered by E. Sternberg.

J. Golecki, Poland

2175. Sokolowski, M., The axially symmetric thermoelastic problem of the infinite cylinder (in English), *Arch. Mech. Stos.* **10**, 6, 811–824, 1958.

General relations for the determination of stresses in infinite cylinder of radius R, due to thermal load, are given in cylindrical co-ordinates. These relations are derived on the basis of the method for integrating the equations of thermoelasticity by means of the so-called thermoelastic potential. The general solution is a sum of the solution corresponding to the thermoelastic potential, the solution of a homogeneous system of Cauchy's equations, and an additional solution determined from the condition of vanishing of stresses at the edge $r = R$.

The starting point for the determination of solutions in particular cases is two basic problems stated by the author and reducing to the determination of the stress distribution in an infinite cylinder, due to a constant temperature distribution T or a uniform distribution of heat sources of intensity W along a circle of radius lying in the plane normal to the axis of the cylinder. The solutions of these problems are obtained by introducing the Dirac function and using Fourier and Hankel transformations. This procedure leads to the determination of the thermoelastic potentials:

$$\Phi(r, z) = -\frac{2cT}{\pi R^2}\rho \int_0^D \sum_n \frac{J_0(\alpha_n \rho) J_0(\alpha_n r)}{J_1^2(\alpha_n R)(\alpha_n^2 + \beta^2)} \cos \beta z d\beta,$$

and

$$\Phi(r, z) = -\frac{2cW}{\pi R^2 \lambda}\rho \int_0^D \sum_n \frac{J_0(\alpha_n \rho) J_0(\alpha_n r)}{J_1^2(\alpha_n R)(\alpha_n^2 + \beta^2)^2} \cos \beta 2 d\beta.$$

J. Golecki, Poland

2176. Markovets, M. P., and Tret'iakov, V. P., Method of determination of resistance to warping at high temperatures, *Indust. Lab.* **24**, 3, 368–369, May 1959. (Translation of *Zavod. Lab., USSR* **24**, 3, 329–331, Mar. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2177. Stavsky, Y., On a cross-elasticity phenomenon in symmetrically nonhomogeneous plates, *J. Aero/Space Sci.* **26**, 9, p. 607 (Readers' Forum), Sept. 1959.

Author considers flexure of a plate which can be anisotropic and inhomogeneous, but the elastic constants are assumed to be symmetrical about the median plane. In the context of classical plate bending theory, expressions are derived for the stresses in terms of the bending and twisting moments. These show coupling in the sense that all stresses are functions of the three moments. Author claims that "in a plate theory which includes transverse shear and normal-stress deformation, the cross-elasticity effects will be shown to be responsible for an increase in the order of plate differential equations and the number of boundary conditions corresponding to it, as compared to the order of the system and the number of boundary conditions for the homogeneous plate. In contrast to this, no such change is encountered in a plate theory without consideration of shear and normal-stress deformation." Justification for this claim apparently will appear in a later article.

J. M. Frankland, USA

2178. Volkov, S. D., The problem of distribution of microscopic stresses and deformations (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 65–72, Mar. 1958.

The distribution of stresses and strains in an elastic body is determined by the solution of the boundary-value problem of the theory of elasticity. But if the body is "microscopically" nonhomogeneous, that is if the elastic moduli are random functions of its points, the solution of a corresponding boundary-value problem determines only "macroscopic" stresses and strains, i.e. the first-order moments of the microscopic distributions of these quantities. A method is outlined in this paper to determine second- and higher-order moments of these distributions.

D. Radenkovic, Yugoslavia

2179. Urbanowski, W., Small deformations superposed on finite deformation of a curvilinearly orthotropic body (in English), *Arch. Mech. Stos.* **11**, 2, 223–241, 1959.

The basic equations of small deformations superposed on finite deformations of a body curvilinearly orthotropic in the undeformed state are considered. Introducing suitable notations and definitions the author derives the expression for the contravariant stress tensor defined as the derivatives of the elastic potential with respect to the covariant strain tensor; the potential is obtained in the form given by Adkins for a homogeneous body characterized by curvilinear orthotropy. Superposing additional state of small strain on the existing state of finite deformations the equation for the additional stress tensor is derived as a function of the strain, general equations for the coefficients which constitute functions of the elastic potential being also derived. The simplification in the case of an indeformable body is discussed. The case of superposition of small strain over a state of homogeneous tension is discussed, assuming rectilinear orthotropy in the undeformed state. It is shown how to use the results for an isotropic body in the case considered.

Finally, the case of superposition of small twist on a state of axial and radial tension of a tube made of an incompressible material characterized by curvilinear orthotropy is considered. The general form of the potential is investigated as well as the equation of equilibrium; the equation for the stress tensor, the additional stress tensor and the torque are obtained.

H. Zorski, Poland

2180. Kartashov, V. A., Regarding an analogy in the theory of elasticity (in Russian), *Trudî Saratovsk. Avtomob.-dor. In-ta* **15**, 1, 42–51, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 687.

With the assistance of a refined transformation of coordinates, determinable by means of the equations $x_1 = k_x x$, $y_1 = k_{yy'} z_1 = k_z z$, the given isotropic elastic body is compared with some orthotropic elastic body.

V. K. Prokopov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2181. Rusch, H., The concept of shear and torsional stresses in the case of multi-axial loading (in German), *Beton u. Stahlbeton.* **53**, 10, 249–250, Oct. 1958.

Author points out that shear (and likewise torsional shear) cannot be used as criterion of strength of structural elements since a judicious choice of coordinates (principal directions) will always bring about a bi- (or tri-) axial stress condition. Only this stress condition can be used as a definition of strength. Reinforcements (particularly in reinforced concrete) must be chosen so as to coincide with the principal directions. More work is needed in order to get a clearer picture of reduction in strength caused by misalignment of principal directions and the direction of reinforcements.

J. Solvey, Australia

2182. Vandyshev, B. A., and Surikova, E. E., The effect of bending in torsion investigations, *Indust. Lab.* **24**, 6, 862–866, June 1959. (Translation of *Zavod. Lab., SSSR* **24**, 6, 764–768, June 1958 by Instrument Society of America, Pittsburgh, Pa.)

2183. Ignat'ev, M. O., Integral presentations of solutions of two basic boundary problems in the theory of elasticity for a sphere (in Russian), *Nauchn. Zap. L'vovsk. Un-ta* **44**, 48–59, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 692.

On the basis of the known properties of spherical functions a number of series is integrated, enabling a presentation to be made of the main problems in the theory of elasticity for a sphere [A. I. Lur'e, "Spatial problems in the theory of elasticity," Moscow, Gostekhizdat, 1955]. An integral presentation is given of the solution of the problem both for the inside of the sphere with the given displacements on its surface, as well as for the exterior of the sphere. The series, with whose help the presentation of the afore-mentioned problems has been given, the boundary conditions being discontinuous, converge slowly, whereas the integral presentation of these problems, as shown in the paper, is free of this disability.

G. N. Savin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2184. Kilchevskii, M. O., Extreme characteristics of the solution of the problem regarding contact compression of elastic bodies (in Ukrainian), *Dop. Akad. Nauk URSR* no. 1, 17–20, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 772.

It is shown that the dynamic problem regarding contact compression of elastic bodies can be solved without recourse to the introduction of supplementary, and more or less arbitrary, hypotheses. The determination is made by the application of the

principle of the least constraint, on which basis the problem reduces to the investigation of the conditional extreme of the integral

$$\iint_{(\omega)} f(M)\, p^2(t, M)\, dS(M)$$

where $f(M)$ is the function depending on the density of the bodies and the thickness of their molecular surface layers, t is time, $p(t, M)$ is the contact pressure, ω is the contact region. The conventional equations appear to be the two equations of the problem in their initial setting. N. A. Rostovtsev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2185. Chattarji, P. P., On the stresses in twisted composite spherically isotropic spheres, *Bull. Calcutta Math. Soc.* **50**, 2, 99–102, June 1958.

A closed form solution is obtained for the stresses in concentric composite spherically isotropic elastic spheres twisted by couples. The results reduce to those for the known case of composite concentric isotropic spheres [AMR **11** (1958), Rev. 1530]. The cases of a thick spherical shell of spherically isotropic material and an elastic outer shell and rigid inner material are also treated as special cases of the general equations.

P. Seide, USA

Viscoelasticity

(See also Revs. 2163, 2170, 2267, 2283)

2186. Jenike, A. W., and Shield, R. T., On the plastic flow of Coulomb solids beyond original failure, *ASME Trans.* **81E** *(J. Appl. Mech.)*, 4, 599–602, Dec. 1959.

Paper deals with a problem encountered in the analysis of flow of soils and in particular the treatment of pulsating flow of a Coulomb solid.

Based upon experimental evidence, authors propose an analytical relation between the mass density and the consolidating hydrostatic pressure by use of two material constants. It is shown that in the state of steady deformation the velocity field may be assumed to satisfy the incompressibility relation. As regards the stress field an "effective" angle of friction larger than the actual angle of friction is introduced.

It should be noted that throughout the analysis the time for soil consolidation was kept constant and the conclusions hold for the process of continued deformation only.

A. Slibar, Germany

2187. Yeh, G. C. K., and Martinek, J., Transient motion of a visco-elastic rectangular plate in fluid media, Proc. Third U. S. Nat. Congr. Appl. Mech., June 1958; Amer. Soc. Mech. Engrs., 1958, 701–707.

General form of transient response of [rectangular] plate in fluid medium is obtained. Authors suggest applying analysis to experimentally determine viscoelastic constants of a material. "Viscoelastic" means "Maxwell solid," with spring and dashpot in series. J. L. Brenner, USA

2188. Ma, B. M., A creep analysis of rotating solid disks, *J. Franklin Inst.* **267**, 2, 149–165, Feb. 1959.

The creep deformation and stress distribution in rotating solid disks operating at elevated temperatures are analyzed by using maximum shear theory. Two alternative creep laws were investigated: (a) the power function, (b) the exponential function. The results, plotted in dimensionless form, are not greatly different for the two laws. Creep strains are somewhat greater than those obtained from distortion energy theory, but are stated to be in good agreement with experimental data. F. R. Shanley, USA

2189. Gintsburg, Ya. S., On the third period of creep and relaxation of stresses (in Russian), *Zavod. Lab.* **23**, 7, 838–842, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 13155.

Tests extending to 10,000-hours duration were carried out on rings of equal resistance to deflection at 560 and 650°, that is at lower and higher temperatures than the critical temperatures of relaxation. In order to disclose the third period, steels were selected whose chemical constitution made it possible to secure a structural condition conforming to that of an exclusively and energetically weakening steel in the relaxational sense. In test conditions at 560° there was not a single case disclosing the third period, whereas all the relaxation curves showed the absence of material relaxation softening; at 650° for all the alloys investigated, a sharp relaxational softening was obtained. Increase of the chromium content in the alloys accelerates the development of the third stage. The latter is observed in the conditions governing the first as well as the second loading. Author holds the view that the appearance of the third period of creep and stress relaxation is innate to every substance capable of viscous flow.

G. F. Lenin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2190. Patel, S. A., Pandalai, K. A. V., and Venkatraman, B., Creep-stress analysis of thin-walled structures, AFOSR TN 59-665 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech. Rep. 497), 40 pp., July 1959.

Authors show that problem is analogous to behavior of equivalent structures made of nonlinear elastic materials. In this way the time factor is removed and a material constant n introduced which depends on the material and temperature at which creep takes place; $n = 1$ for linear elastic behavior. Authors first consider problem of creep under torsion of multi-cell thin-walled structures and derive expressions for shear flow and torque-twist relations for one-, two- and three-cell sections. Numerical comparisons are made for $n = 1$ to ∞. Consideration of nonlinear elastic behavior is made to investigate bending of thin-walled open-section beams. Expressions are derived for position of neutral axis for given direction of applied moment vector under unsymmetric bending. Numerical comparison is made with linear elastic behavior. Thereafter expressions are given for bending stress distribution.

After considering simpler case of symmetric bending authors consider shear stress distribution and derive expression for determination of shear center. They demonstrate important difference with linear elastic behavior that position of shear center is dependent on direction of action of shear force as well as on the geometry of the section. This difference is confirmed also for thin-walled sections. Finally, bending and shear in circular cylinders with longitudinal stiffeners is investigated as example of extension of approach.

This excellent work, although done primarily for aircraft structures, would be applicable to many other engineering problems. Presentation is good and results are readily applicable in a design office. Work is restricted to creep at constant temperature. Change in temperature would, for example, cause change in the value of n and complicate solution. Nevertheless, solution of many structures is accurate enough on basis of constant temperature. G. Little, England

2191. Bol'shanina, M. A., and Donets, A. T., On the question of the influence of the velocity of deformation on the process of relaxation (in Russian), *Izv. Vyssb. Uchibn. Zavedenii. Fizika* no. 1, 17–22, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 13596.

The relaxation of stresses was studied with different velocities of deformation (from 0.025 to 74.4 revs/min) and at different temperatures (from 17 to 400°). The mean velocity of relaxation was evaluated by means of the coefficient of repose a, which was determined from the curves "torsion moment—time" by the formula $a = \Delta M / M_0 M \Delta t$, where M_0 is the torsion moment corresponding to the end of the deformation and the beginning of the relaxation, ΔM is the lowering of the torsion moment by the time of the relaxation of Δt secs. It is shown that with increase in the velocity of the deformation the initial velocity of the relaxation increases in the period of time when the torsion moment shows hardly any change. The results obtained are explained by the presence of less stable distortions of the crystalline lattice at a high rate of the deformation. It was established that with temperatures up to 200° the mean velocity of relaxation depends linearly on the logarithm of the deformation velocity; at higher temperatures a more complex relationship is observable. G. A. Tulyakov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Plasticity

(See also Revs. 2186, 2190, 2215, 2224, 2226, 2234, 2248, 2249, 2254, 2256, 2260, 2262, 2263, 2270, 2286, 2287, 2291)

2192. Ivlev, D. D., Certain particular solutions of equations for the axisymmetrical problem in the theory of ideal plasticity and generalization of Prandtl's solution of compression of plastic layer between two rough plates, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22**, 5, 943–951, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author considers certain particular solutions employing Mises and Tresca-Saint-Venant conditions, and associate laws of plastic flow. Author observes that particular results are analogous to cycloidal solutions by Prandtl. Author refers to detailed contributions on this subject by: Sokolovsnii, V. V., Mikhlin, S. G., Hill, R., Shield, R. T. and Hecky, H. and confines his efforts to pointing out situations under which Prandtl's relationships are obtained. In employing Mises' conditions, author started with equations in cylindrical coordinates in terms of dimensionless quantities. In employing Tresca-Saint-Venant's conditions, author presupposed conditions of complete plasticity to be satisfied. Author verified this assumption by developing complete solutions. Transformation of variables was used for statically determinate hyperbolic equations, so that characteristics would coincide with slip lines. Good results are anticipated for cases when stress state differs substantially from state of plane strain. V. A. Valey, USA

2193. Sobolevskii, V. M., Elastic and elastic-plastic stressed state of a slanting sphere in an elastic medium under the action of an internal pressure and a radial thermal flow (in Russian), *Izv. Vyssh. Uchebn. Zavedenii Energetika* no. 3, 103–110, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 800.

The stressed state is investigated of a slanting sphere under the action of an even pressure from the inner side and of a pressure of an elastic Hooke medium or a linearly pliable Winkler medium and a radial thermal flow from the outer side. Formulas are found for the stresses and radial transpositions in the sphere and the elastic medium for the cases:

(1) The elastic stressed state of a slanting sphere;

(2) The elastic-plastic stressed state of a slanting sphere.

For the same cases formulas are found for the stresses and radial transpositions in a sphere subjected from the outer side to the pressure of a pliable Winkler medium. I. N. Danilova

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2194. Kolesnikov, A. L., Approximate method for determining the critical force for an eccentrically compressed hinge-supported rod in elastoplastic stage (in Russian), *Trudi Kbar'kovsk. Inzh.-Stroit. In-ta* no. 5, 111–114, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 806.

The essence of the proposed method lies in the following, the form of deflection is assigned, the unknown coefficient is expressed through the curvature in the mean section so that the external deflection moment in the mean section is found to be the linear function of the unknown curvature K_{mean}, $M = P(a + b\,k_{mean})$ [1]. Having set the value of the curvature in the mean section and of the mean deformation e_0, it is possible to find the linear deformations by the formula $e = e_0 + k_x$ where the curvature in the section being examined is linearly linked with the curvature k_{mean} in the mean section. By determining on the curve's shape $\sigma - \epsilon$ the values of the stresses it is possible to find the link $P(e_0, k_{mean})$ and $M(e_0, k_{mean})$ and then by means of a few trials to find the value for e_0 at which point P falls on the straight line [1] (with the value of k_{mean} assigned). This state will correspond to the equilibrium state. In this way it will be possible to construct the link $M = f(P)$ for the equilibrium state and the critical load will be determinable graphically as the abscissa of the point with a vertical tangential. A. A. Kurdyumov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2195. Galperin, A. I., The question of tube deflection beyond the elastic limit (in Russian), *Trudi Vses. N.-i. In-ta po Str-vu Obiektov Neft. i Gaz. Prom-sti* no. 9, 111–121, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 807.

An approximate analysis is given of the deformations and stresses during elastic-plastic deformation of a tube (applicable to the bending of tubes in tube-bending plant). It is assumed that the material of the tubes does not toughen.

L. M. Kachanov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2196. Hwang, C., Incremental stress-strain law applied to work-hardening plastic materials, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 594–598, Dec. 1959.

Paper treats the bending of a thin plane plate of rigid-plastic work-hardening material using the yield condition of von Mises. The form of work-hardening assumed is one in which the gradient of the equivalent stress versus equivalent plastic strain curve is constant. The theory is applied to a simply supported circular disk under an increasing uniform normal pressure. The resulting difference equations are solved by the NCR 304 digital computer.

W. M. Shepherd, England

2197. Kumar, S., Basic analysis of scabbing in materials, Proc. 3rd Congr. Theor. Appl. Mech., Bangalore, India; Indian Soc. Theor. Appl. Mech., Indian Inst. Technol., Kharagpur, 1957, 145–156.

Author describes the concepts of "scabbing" and "spalling" in basic, mathematical language. The elastic analysis for uniaxially stressed bars, edge-stressed plates with bi-axial stress distribution, and plates uniformly stressed with compressive forces is given. From this mathematics, and assuming a steel with a Poisson ratio of 0.3, the pressure required for fracture in an edge-loaded plate is 12 ½% larger than for a bar, while in plane strain propagation in a plate (compression loading) it is 75% larger than a bar. The "effective" stress concept is the criterion for failure. An elastoplastic analysis of the same three problems is made by assuming an idealized stress-strain curve with two distinct slopes and one point of discontinuity (the yield point).

An abbreviated description of a graphical method for analyzing

an "elastoplastic" wave is given and an experiment with an aluminum 14ST-4 bar described. No fracture was obtained and it is concluded that plasticity of the materials is a desirable property if scabbing is to be avoided. Many more experiments will be required to provide a correlation between the theory and reality.

The paper is a bold attempt to simplify, condense, and describe a complex physical phenomenon. R. H. Carey, USA

2198. Kalnins, A., On plane-stress solution of a compressible wedge with the use of Mises' yield condition, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 676–678 (Brief Notes), Dec. 1959.

The purpose of this note is to present a complete solution for an acute, compressible, elastic, perfectly plastic wedge in the state of plane stress subjected to uniform pressure on one face, employing Mises' yield condition and its associated flow rules, and thereby to offer a comparison with the solution given previously by P. M. Naghdi. From author's summary

2199. Zaid, M., Concerning the further understanding of the shakedown theorems used for structural analysis, *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 462–463 (Brief Notes), Sept. 1959.

It is the purpose of this note to clarify certain concepts that are basic to the use of the shakedown theorems associated with an ideally plastic material. Although the discussion is intended to apply specifically to two-dimensional frame-type structures, the complete understanding of such structures is useful in the extension of theory to more complex problems.

From author's summary

2200. Goloskokov, P. G., Making use of residual stresses in order to increase the strength of rotating discs (in Russian), *Trudi Leningrad In-ta Inzb. Vodn. Transp.* no. 24, 196–203, 1957; *Ref. Zh. Mekh.* no. 10, 1958, Rev. 11811.

This is a theoretical investigation of the toughening effect of residual stresses appearing in rotating disks as the result of initial acceleration.

From author's summary
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Rods, Beams and Strings

(See Revs. 2190, 2226, 2234, 2306)

Plates, Shells and Membranes

(See also Revs. 2172, 2177, 2181, 2196, 2230, 2234, 2236, 2237, 2238, 2260, 2262, 2269, 2273, 2274, 2321, 2586)

2201. Hicks, R., Symmetrically loaded circular plates under the combined action of lateral and end loading, *Aero. Quart.* **10**, 3, 266–282, Aug. 1959.

In this paper, expressions are obtained for the radial and tangential bending moments and for the deflection surface of a circular plate submitted to the simultaneous action of an end tension or compression and either a lateral load concentrated on the circumference of a circle or a uniformly distributed lateral load having a diameter less than the diameter of the plate. Solutions are obtained for plates which are simply supported and for plates with an arbitrary end rotation. Limiting cases are also considered. The problems are solved using the approximate equation for thin plates with small deflections in which the effect of the transverse component of the radial tension or compression owing to the slope of the deformed plate is added to the shear due to the lateral forces. Four other papers in which different authors have studied similar problems are briefly discussed.

H. C. Reggini, Argentina

2202. Tomate, O., Transverse flexure of a semi-infinite thin plate containing an infinite row of circular holes, *ASME Trans.* **81**E (*J. Appl. Mech.*) 4, 661–665, Dec. 1959.

The title problem has been solved by using the Poisson-Kirchoff theory of thin plates for the case of an infinite row of equal and equally spaced holes.

Parametric coefficients included in the deflection of the plate are obtained by a perturbation method. In several cases, numerical values for the maximum bending moments on the rim of the hole across the minimum section are calculated and discussed.

S. C. Das, India

2203. Mednikov, I. A., A general formula for the tangential stresses in the horizontal sections of a plate (in Russian), *Trudi Mosk. Avtomob.-dor. In-ta* no. 20, 153–160, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 741.

A derivation is given for the formulas for the tangential stresses X_z and Y_z brought in to the transverse forces of the plate. It is assumed that apart from the external load massive forces of constant intensitivity are acting on the plate. The formulas for X_z and Y_z are obtained by the integration of the equations of equilibrium for the spatial problem. When deriving the formula it is assumed that the stresses X_x, Y_y and X_y change with the thickness of the plate in accordance with the plane principle, the plate being examined as a plane. V. V. Vlasov

Courtesy Referativnyi Zhurnal, USSR
Translation courtesy Ministry of Supply, England

2204. Feodosiev, R.-E. V., Deflection of an anisotropic triangular plate (in Russian), *Uch. Zap. Kishinevsk. In-ta* **29**, 77–88, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 742.

Using the Ritz method the problem is solved regarding the deflection of an orthotropic plate in the form of an equally ribbed triangle under the action of an evenly distributed load, normal to the plane of the plate. Three variants of the fastening of the sides of the triangle are gone into: (1) all three sides are firmly clamped; (2) one side is firmly clamped while the other two are freely supported; (3) two sides are firmly clamped while the third side is freely supported. Numerical results are given for the maximum deflection in plates made of veneer wood and steel for all the cases investigated. A. S. Kosmodamianskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2205. Tulchii, V. I., Deflection of an infinite plate weakened by two round orifices, the edges of which are strengthened by thin rings, Part 3 (in Russian), *Dop. L'vovsk. in-ta* no. 7, 296–308, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 747.

A solution is given for the title problem; the rings are of constant section; the stressed condition is homogeneous to infinity. The strengthened ring is investigated as a thin elastic rod with equal flexibility in deflection and torsion. The problem is solved by the method of functions of a complex variable.

M. Ya. Leonov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2206. Varvak, P. M., and Guberman, I. O., Calculations for rectangular plates clamped on their contours (in Russian), *Sb. Trudi In-ta Stroit-Mekh. Akad. Nauk SSSR* no. 21, 51–68, 1956; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 752.

The calculations for the plates are made numerically. The dif-

ferential equation for the deflection is presented in end differences. The method of calculation makes it possible to take into account the given transpositions of points on the contour. A large number of auxiliary tables are published for plates with different side ratios. An example is investigated of a plate in the shape of a square.

N. S. Kurdin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2207. Broglio, L., An exact solution for free rectangular plates laterally loaded (in Italian), *Monogr. Scient. Aero.* no. 4, 75 pp., Dec. 1958.

This interesting paper gives method to solve problem of free rectangular plate of constant thickness subjected to arbitrarily distributed load normal to its plane. Given loading is first reduced to system of edge loads only. This is done by determining some function w_1, satisfying plate equation $\nabla\nabla w = q$ (q = given loading) and decomposing loading into load system corresponding to this particular solution of plate equation (i.e. actual loading plus system of edge loads) and reverse of edge loads of this system. Once w_1 has been found, only solution for latter edge load system need be determined.

Edge load system can always be composed of six "standard" systems, for which solutions are developed in paper. These solutions are approximate in that infinite series contained in one of boundary conditions at each edge are cut off after certain number of terms. Author states that convergence is very good. Numerical example for simple loading case concludes paper.

In reviewer's opinion author might have explained reduction of actual loading to system of edge loads in more detail and devoted more attention to determination of particular solutions w_1 mentioned above. Reviewer further remarks that deviations of curves $\zeta = 1$ in Figs. 3.3, 3.6 and 3.9 from $m_x = (1-\eta)^2$ give some indication of accuracy of solution and that he observed some printing errors in Eqs. (2.3) and (2.25).

F. J. Plantema, Holland

2208. Dem'ianov, Iu. A., Self-modelling problems in the dynamic bending of plates, *Soviet Phys.-Doklady* **3**, 1, 197–198, Dec. 1958. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **118**, 4, 669–670, Jan./Feb. 1958 by Amer. Inst. Phys., Inc., New York, N. Y.).

2209. Simeonov, S. V., Calculations for flexible plates, reinforced by elastic ribs (in Russian), Avtoref. Diss. Kand. Tekhn. Nauk, Leningrad Korablestroit. In-ta, Leningrad, 1957; *Ref. Zh. Mekh.* no. 5, 1958, Rev. 5747.

2210. Gogsadze, R. Sh., Some boundary problems in the theory of elasticity for a plane compound region (in Russian), *Trudi Gruz. Politekhn. In-ta* no. 4/52, 107–134, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12984.

Investigations are made of the boundary problems of the deflection of a thin plate, of the first and second problems of the plane theory of elasticity for regions formed by different elastic materials, and of some auxiliary problems [see N. I. Muskhelishvili, "Some fundamental problems in the mathematical theory of elasticity," Moscow, Izd-vo Akad. Nauk SSSR, 1949]. Author, adopting the Kolosov-Muskhelishvili method, brings the solution of these problems to the solution of a single boundary problem in the theory of the function of a complex variable. The case is separately investigated where the region consists of two regions: an ellipse and a confocal elliptical ring.

A. Ya. Gorgidze

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2211. Bleich, H. H., and Salvadori, M. G., Bending moments on shell boundaries, *Proc. Amer. Soc. Civ. Engrs.* **85**, ST 8 (*J. Struct. Div.*), 91–101, Oct. 1959.

A comparison is made of bending stresses due to applied boundary moments in flat plates, cylindrical shells, rotational shells, and saddle shells. The comparison illustrates the mechanism of bending stress penetration in the most commonly used types of thin shells. The behavior of the shallow hyperbolic paraboloid supported along four straight generatrices is studied by means of Vlasov-type equations. The boundary disturbances to be added to the membrane stresses are known quantitatively in a rather special case, and only qualitatively in the general case. Their determination remains open to discussion.

From authors' summary by R. Diaz de Cossio, Mexico

2212. Schile, R., Analysis of thin conical shells under asymmetric loading, Proc. Fourth Midwest Conf. Solid Mech., Austin, Texas, Sept. 1959; Austin, Texas, Univ. Press, 195–206.

Author bases his analysis on Novožhilov's complex fourth-order equations for the shell of revolution of constant wall thickness. Assuming a sinusoidal edge loading and neglecting body forces, a solution of Novožhilov's equations for the conical shell is obtained in a closed complex form. Next, a solution for any arbitrary edge loading, assumed in the form of a Fourier series, is also derived by means of a perturbation procedure. Author remarks that although the convergence of the solution for arbitrary edge forces is established, the number of terms that must be taken is excessively large. Numerical examples are not presented in the paper.

Z. Karni, Israel

2213. Au, T., Equations for thin toroidal shells, *J. Aero/Space Sci.* **26**, 6, 391–392 (Readers' Forum), June 1959.

2214. Oravas, G.-A., Transverse flexure of shallow barrel shells, *Trans. Engng. Inst. Canada* **3**, 1, 23–31, Apr. 1959.

Author obtains approximate series solution for shallow shells of cylindrical form, bounded by two transverse cross sections and by "barrel-shaped" longitudinal edges. Equations of shallow-shell theory are satisfied rigorously by series solution, consisting of a particular solution and a number of complementary functions; the complementary functions satisfy a wave-type equation, and are derived by introducing polar coordinates in the base plane of projection of the shell middle surface. Boundary conditions are satisfied in isolated collocation points. Adequate accuracy for practical design is claimed if 12 collocation points distributed around entire boundary are used.

W. T. Koiter, Holland

2215. Drucker, D. C., and Shield, R. T., Limit analysis of symmetrically loaded thin shells of revolution, *ASME Trans.* **81**E (*J. Appl. Mech.*), 1, 61–68, Mar. 1959.

The yield surface for a thin cylindrical shell is shown to be a very good approximation to the yield surface for any symmetrically loaded thin shell of revolution. Hexagonal prism approximation to this yield surface, appropriate for pressure-vessel analysis, is described and discussed in terms of limit analysis. Procedures suitable for finding upper and lower bounds on the limit pressure for the complete vessel are developed and evaluated. They are applied for illustration to a portion of a toroidal zone or knuckle held rigidly at the two bounding planes. The combined end force and moment which can be carried by an unflanged cylinder also is discussed.

A. W. Coutris, USA

2216. Bartenev, V. S., A practical method of calculation for coverings in the form of ferroconcrete round cylindrical shells (in Russian), *Sb. Trudi Mosk. Inzb. Stroit. In-ta* no. 11, 116–151, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 731.

This is an investigation of practical calculations for thin slanting round cylindrical shells of medium length, disregarding the torsional moments, the longitudinal deflection moments, the transverse forces, the transverse elongations and shearing of the median

surface of the shell [see: G. Elers, In: "Wrinkled ferroconcrete constructions," Kharkov, 1934, and also *Bauingenieur* no. 8, 1930; G. Kremer. In: "Wrinkled ferroconcrete constructions," Kharkov, 1934]. A method is given for the calculations for the given shell (linked monolithically with the other elements along the rectilinear longitudinal edges) by means of the derivation and solutions of three joint canonical equations for the border conditions, with subsequent application of the prepared formulas. Tables are furnished for the determination of the coefficients of influence for the external loads and single force and deformation factors, applied to the longitudinal edges of the hinge-supported shell, which is accepted as the fundamental system when static indeterminability is disclosed. A numerical example for a cylindrical shell is given, the shell being strengthened along its longitudinal edges by stays and supported by a row of columns close to each other. The results are compared with the calculations of a shell viewed as a fold [see: V. Z. Vlasov, "The general theory of shells," Moscow-Leningrad, Gostekhteorizdat, 1949]. V. G. Rekach

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2217. Zharmagambetov, B. S., A new method for calculating ferroconcrete structures of the type of slanting thin-walled spherical shells of variable thickness (in Russian), Izv. Akad. Nauk KazSSR, Ser. Gorn. dela, Metallurgi, Str-va i Stroimaterialov no. 3, 3-12, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 732.

The boundary problem is investigated regarding slanting spherical shells of variable thickness, subjected to axially symmetrical deformation. The initial equations appear to be Meissner's differential equations [E. Meissner, *Vierteljahrsschr., Naturforsch. Ges. Zürich* **60**, no. 3, 1915]. It is accepted that the thickness of the shell changes proportionally to the distance of a point on the mean surface to the axis of symmetry; Poisson's coefficient is taken to be equal to zero; the solution is obtained in terms of Bessel functions. Approximate formulas are given for the deflection moments, for forces in the median surface and transpositions. Particular cases are examined of the loading of the shell along the edges by forces, the plane of which is perpendicular to the axis of symmetry or the moments. A. S. Volmir

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2218. Lunchick, M. E., and Overby, J. A., An experimental investigation of the yield strength of a machined ring-stiffened cylindrical shell (Model BR-7M) under hydrostatic pressure, David W. Taylor Mod. Basin Rep. 1255, 19 pp., Nov. 1958.

The effects of initial imperfections and residual welding and rolling stresses on the yield strength of a stiffened cylinder were investigated by tests of a machined and stress-relieved model, Model BR-7M, identical in geometry and of the same material as a previously tested fabricated model, Model BR-7. The experimental collapse pressure of 1502 psi agreed well with collapse pressures computed from theories which account for the plastic reserve strength. The pressure at which yielding began agreed more closely with that calculated by the maximum-shear-stress or the Hencky-Von Mises criterion than with that calculated by the maximum-principal-stress criterion. The data also indicated that the mathematical form of the deflection function of the shell did not change appreciably in the elastic-plastic range. Comparison of the collapse pressures of the machined and welded models indicated that, for the geometry tested, the residual welding and rolling stresses do not adversely affect the collapse pressure.

From authors' summary

2219. Aksel'rad, E. L., On the theory of heterogeneous isotropic shells (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 6, 73-76, June 1958.

The basic equations of shell theory are reviewed for two-layer shells. Particular attention is given to the relations between the stress resultants and membrane and bending strains for bimetallic combinations. F. T. Geyling, USA

2220. Bolotin, V. V., Statistical methods in the nonlinear theory of elastic shells (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 33-41, Mar. 1958.

Paper deals with the problem of the stability of elastic shells. The value of the critical load under which a shell buckles "as a whole" depends on many factors (initial curvature, defects in manufacturing, uneven distribution of loading, etc.) which bear a random character. For a given probability distribution of these factors the magnitude of loading can be determined for which the probability of a critical event (e.g. buckling) will not exceed a certain prescribed value. Such statistical approach presents also a rational basis for the discussion of the results of experiments made under different circumstances by different authors.

D. Radenkovic, Yugoslavia

2221. Marciniak, Z., Determination of the form of membrane-type shells in the plastic state (in Polish), *Rozprawy Inz.* **6**, 3, 425-494, 1958.

Author analyzes the possible forms of a shell of revolution with no flexural rigidity and subjected to perfectly plastic deformation, as a result of axially symmetric load acting normally to the middle surface of the shell and longitudinal forces distributed uniformly along its edges.

From the equations of equilibrium of an element of a shell of revolution and from the Huber-Mises-Hencky yield condition and using the solution method of A. Nadai, the author formulates the relations between the internal forces and the distance of the element of the shell from the axis. Using the most simple example of a plane ring loaded on the edges, author distinguishes four groups of possible stress distributions in the plastic state. Next, he is concerned with shells subjected to the action of uniform normal pressure and proposes a graphical method for determining the form of these shells.

Finally he presents examples of deformation of shells in various cases of load and discusses their realizations in the process of forming thin sheet metal.

The problem of sheet metal forming, which, in the literature, is reduced to that of determining the forces necessary for obtaining the desired deformations, is treated by the author from another viewpoint. J. Murzewski, Poland

2222. Galimov, K. Z., Certain problems of nonlinear shell theory (in Russian), Avtoref. Diss. Dokt. Fiz.-Matem. Nauk, In-ta Mekhan. Akad. Nauk SSSR, Moscow, 1957; *Ref. Zh. Mekh.* no. 7, 1958, Rev. 7894.

2223. Wicke, M., Computation of polygonal containers (in German), *Öst. Ingenieur Z.* **2**, 7, 260-265, July 1959.

Paper deals with the calculation of the stresses in the walls of reservoirs with horizontal surfaces of regular polygonal shapes and vertical faces rectangular. The internal pressure displaces the vertical edges symmetrically. This edge displacement is related to cross-sectional forces by the use of plane-stress theory. The vertical faces are treated with the usual plate theory, the deflection now having an additional component due to this edge displacement. The horizontal edges are taken as supported and the vertical ones as clamped but with prescribed displacements arising from the edge displacement. Resolution in the direction from the axis to a vertical edge leads to an additional condition to determine this. Numerical results show that this edge displacement tends to reduce the moments in the horizontal strips.

G. A. Nariboli, India

2224. Hao, T.-C., and Wang, J., A note on the minimum weight design of pressure vessel for the intermittent type supersonic wind tunnel, *Scientia Sinica* **8,** 5, 461–467, May 1959.

Introduction contains familiar description of supersonic intermittent-type tunnel. For selected tunnel and testing time author attempts to determine optimum (highest, initial) pressure in vessel which would result in minimum weight vessel. Using Laval nozzle theory and starting with equations of rate of mass flow at test section, author develops equations of rate of mass change for pressure vessel. Isothermal condition is assumed inside of pressure vessel and adiabatic one at flow from pressure vessel to regulator. Particular cases for certain assumed powers for both processes are investigated. Author proceeds with cylinder's design and feels that, since wall thickness is small, ideal plasticity may be considered. Tresca's yield condition is used. Elastic limiting pressure is determined when initiation of plastic region occurs at inner wall. Plastic limiting pressure occurs when plastic region reaches outer wall. Author expresses outer radius in terms of inner radius, expands above expressions, and observes that expressions differ beyond terms. Author allows this difference to be neglected. Intentional neglecting of change in weight of cylinder's end sections leads to expression for weight. By finding minimum of this function formula for minimum weight of vessel is obtained. Author also considers spherical shell as example. Finally, author observes that for particular wind-tunnel design there exists optimum value for initial pressure in vessel leading to selection of minimum weight vessel. For small Mach number of less than 3, initial pressure is less than 40 atm, and there will be hardly a difference between elastic and plastic designs. For Mach number of 5 and larger, initial pressure increases to 200 atm and plastic design conditions may be more advantageous.

V. A. Valey, USA

2225. Baltrukonis, J. H., Influence coefficients for edge-loaded short, thin, conical frustums, *ASME Trans.* **81**E (*J. Appl. Mech.*), 2, 241–245, June 1959.

An exact solution is obtained in terms of Kelvin functions for axisymmetrically edge-loaded, short, thin, conical frustums. Expressions for the edge-deflectional and rotational influence coefficients are presented in matrix form. Approximate expressions for the influence coefficients are evolved by using one-term asymptotic expansions for the Kelvin functions. It is shown that the range of validity is somewhat larger for this approximate solution than for the solution by Horvay, Linkous, and Born.

From author's summary by H. Beer, Austria

Buckling

(See also Revs. 2157, 2220, 2236)

2226. Reggini, H. C., Buckling: Numerical calculations corresponding to the linear and nonlinear regions (in Spanish), Centro Estudiantes de Ingenieria, La Linea Recta, 18 pp., Oct. 1958.

Paper applies finite difference method with matrix iteration to obtain the critical load of a tapered column with pinned ends. No discussion of accuracy of method is given and author fails to point out that the simple Rayleigh method, which he quotes as giving too high a result, actually gives a very much smaller overestimate than the underestimate given by the finite difference method using four intermediate station points.

Second part of paper is a brief exposition of the Engesser-Karman method for plastic buckling of columns.

P. C. Dunne, Brazil

2227. Lee, L. H. N., On the lateral buckling of a tapered narrow rectangular beam *ASME Trans.* **81**E (*J. Appl. Mech.*), 3, 457–458 (Brief Notes), Sept. 1959.

In this note the elastic lateral buckling of a tapered rectangular beam subjected to pure bending in its plane is considered.

From author's summary

2228. Marciniak, Z., Graphical determination of stress distribution in sheet strips subjected to plastic bending, the axial force being taken into consideration (in Polish), *Rozprawy Inz.* **6,** 4, 539–545, 1958.

The case under consideration is that of cylindrical buckling of steel strips, wide in comparison to the thickness, due to the action of a bending moment and a tensile force. An approximate graphical method is given for the determination of the stress distribution in the sheet loaded in the above manner, with the following conditions: (1) the curvature radius after bending is considerable in relation to the thickness; (2) the deformation in the direction of the generant is constant for every point of the cross section; (3) the material is elastic-plastic; (4) the deformation is proportional.

With these assumptions, equations for the pressure of the sheet against the die and the value of the axial force depending on the difference of the substitute strains of external and internal fibers are derived.

Using the graphical method proposed in one of the author's previous papers, the geometrical interpretation of the state of strain is analyzed for various bending modes. A method is given for the geometrical determination of the stress components and illustrated by a practical example. W. Szczepinski, Poland

2229. Weikel, R. C., and Kobayashi, A. S., On the local elastic stability of honeycomb face plate subjected to uniaxial compression, *J. Aero/Space Sci.* **26,** 10, 672–674 (Readers' Forum), Oct. 1959.

It is the purpose of this note to estimate the critical load at which intracell buckling and/or wrinkling occur by considering the elastic stability of the face plate within a honeycomb cell where the face plate is simply supported at its four edges by an elastic core.

From authors' summary

2230. Keller, H. B., and Reiss, E. L., Spherical cap snapping, *J. Aero/Space Sci.* **26,** 10, 643–652, Oct. 1959.

Computing machine solutions of the finite difference equations of pressurized spherical shells with built-in edges are presented. Snap-through buckling is found in agreement with usual understanding of problem, but indications are found that the buckling and prebuckling behavior are very much more complicated than is usually thought, and this complication is more pronounced for increasingly thin shells. G. W. Housner, USA

2231. D'Arga e Lima, J., Buckling formulas for the design of steel towers (in Portuguese), Minis. Obras Publicas., Lab. Engen. Civ., Lisboa, Mem. 110, 16 pp., 1957.

Supplementing the study of buckling of constant section columns that has been under way at the Laboratório Nacional de Engenharia Civil, some considerations are presented concerning the particular case of transmission towers with a view to recommending design formulas applicable to them. A short summary of the actual position of the problem is given, then some design methods are analyzed and the conclusion is reached that two of the methods are founded on reliable theoretical and experimental bases. They are, therefore, recommended for the design of screwed steel towers for high-tension electric lines. From author's summary

Vibrations of Solids

(See also Revs. 2137, 2323, 2332, 2586, 2654)

2232. Bogusz, W., Vibration of bars on movable supports (in Polish), *Rozprawy Inz.* **7,** 2, 169–180, 1959.

The amplitudes and support reactions due to the vibration of a shaft rotating with constant speed and supported on fixed end bearings and an intermediate bearing moving with constant velocity are considered.

Using the general solutions obtained by means of Volterra integral equations and expanding the kernel in a Fourier series the author shows the possibility of instability of the vibrating motion for a certain critical displacement rate of the intermediate support. In addition, the presence of the intermediate support results in a decrease of the critical speed in comparison to a shaft on two bearings.

The method described presents the possibility of generalizing the solutions to the case of any finite number of supports.

M. Lawina, Poland

2233. Ryazanova, M. Ya., Vibrations in a beam under the action of a load travelling along it (in Ukrainian), *Dop. Akad. Nauk URSR* no. 2, 157–161, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 787.

The problem is examined regarding the vibrations of a load moving according to the given principle along an elastic beam of finite length. The problem is brought to an integral equation having the form

$$\int_0^t L(t, t_1)\,\varphi(t_1)\,dt_1 = F(t)$$

where the nucleus $L(t, t_1)$ and the free term $F(t)$ are known functions, expressed through the fundamental functions when the method of clamping the ends of the beam is assigned; $\varphi(t_1)$ is the function being sought. The loads' ordinate $y(t)$ is found by the following formula

$$y = \int_0^t (t - t_1)\,\varphi(t_1)\,dt_1$$

The integral equation is solved approximately by the substitution of the integral by an amount. A numerical calculation is made for the case of an evenly accelerated motion of the load.

Ya.S. Uflyand

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2234. Galin, M. P., Transverse vibrations of beams and plates, subjected to impulsive and impact loads, beyond the elastic limit (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 42–50, Mar. 1958.

In this article the problem is solved of vibration of beams of rectangular cross section and of plates when the stress exceeds in any point the elastic limit. A linear stiffening of material over elastic limit is supposed. The solution of plate is for $m = 2$. Influence of shear and rotatory inertia is neglected.

Equations of motion for undamped elastic vibration are used. Influence of plastic deformation is expressed by supplementary fictive load containing nonlinear terms. The solution of the equations of motion is supposed to be a series of eigenfunctions of elastic vibrations and is based on the method of successive approximations. Elastic vibration is taken for the first approximation.

A numerical example of a beam under sudden impulse is added. The nomenclature of the members in [1, 17] is not suitable with regard to the nomenclature of functions $y_k(\tau)$ in [1, 12]. The progress and nomenclature used in the example do not correspond exactly with the general solution.

In the opinion of the reviewer there is given a useful solution of many technical problems. It would have been desirable therefore to add a numerical example of the solution of the plate.

V. Petrovsky, Czechoslovakia

2235. Kiseleva, I. V., Vibrations of a rectangular orthotropic plate supported along the contour, taking into account a concentrated mass at the place of application of a vibrating load (in Russian), *Trudi Mosk. Avtomob. dor. In-ta* no. 21, 129–132, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 782.

A differential equation is derived for the constrained vibrations of a rectangular plate lying on an elastic foundation and possessing a concentrated mass. The solution of this equation in the case of the free support of the plate's edges is sought in the form of double trigonometrical series. After determining the coefficients, the value for the deflection at the place of application of the load and the action of the vibrating load are found.

V. E. Breslavskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2236. Herrmann, G., and Armenakas, A., Vibrations and stability of plates under initial stress, Columbia Univ., Dept. Civ. Engng. and Engng. Mech., Inst. Flight Struct. CU-2-59-AF-430-CE, 51 pp., Feb. 1959.

In authors' terminology, a strut under end-thrust is said to be subjected to "initial stress." Existence of this may substantially alter the static and dynamic behavior of the strut. In theory of plates, initial stress investigations have been concerned with initial "membrane" stresses only. In present theoretical paper authors relax restriction to membrane stresses. Equations of motion are obtained by linearizing nonlinear plate equations. Effects of initial stresses on natural frequencies are traced.

R. E. D. Bishop, England

2237. Yu, Y.-Y., Simple thickness-shear modes of vibration in infinite sandwich plates, AFOSR TN 58-897 (Polyt. Inst. Brooklyn, Dept. Mech. Engng.; ASTIA AD 204 132), 15 pp., Oct. 1958.

Author considers title problem for sandwich plates consisting of three layers symmetrically arranged. Solutions in closed form are obtained for the case of plane strain, using elasticity theory. By comparing the lowest frequency of the antisymmetric mode with its value from his one-dimensional sandwich-plate theory [AFOSR TN 58-896, 1958 or *J. Appl. Mech.* **26**, 415–421, 1959], author shows that the shear coefficient depends on the parameters of the plate and in practical cases has a value very close to unity, in contrast to its value of $\pi^2/12$ for homogeneous plates.

G. B. Warburton, Scotland

2238. Sokolov, F. A., Vibrations of a free plate and a plate on an elastic foundation subjected to dynamic loading (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* No. 6, 114–117, June 1958.

Vibrations of an infinite free plate and plate on elastic foundation under sudden uniform circular load (Heaviside's function) are solved by means of Laplace-Wagner transformation. The equation of motion is written in polar coordinates.

Expressions for deflection and bending moment in the center of load are given.

From this solution different cases of axial symmetrical circular load are then easily derived, such as impulse of arbitrary duration, uniform load as arbitrary function of time, sudden load as arbitrary function of radius, and load which can be expressed as a linear combination of last two cases.

The solution of the plate on elastic foundation can also be used for a slightly curved spherical shell, this problem being expressed by the same differential equation.

The solution presented is a fine example of suitability of Laplace-Wagner transformation for cases where the classical method is lengthy. A few printing errors are easily corrected by the reader.

V. Petrovsky, Czechoslovakia

2239. Kaliski, S., Non-steady forced vibration of a rectangular parallelepiped (in English), *Arch. Mech. Stos.* **10**, 5, 727–745, 1958.

The subject of this paper is an isotropic elastic parallelepiped with all the walls fixed. In the basic layout a parallelepiped is assumed in which points lying on the surface may undergo only normal displacement. For this scheme dynamic Green's functions are found constituting displacements due to the unit impulse applied at any point and acting in any direction. Time-variable normal loads treated as unknown act on the walls of the rectangular parallelepiped. From the condition that the displacements of all the points lying on the bounding surface should at any time be equal to zero we obtain a system of six integral equations containing the unknown functions.

Performing the Laplace transformation and making use of the symmetry of the system, full regularity of the systems of algebraic equations thus obtained is shown. To do this the author's criteria introduced in the paper "The dynamical problem of the rectangular parallelepiped [*Arch. Mech. Stos.* **10**, no. 3, 1958; AMR **12** (1959), Rev. 1806] are used. The possibility of obtaining the solution by means of an infinite system of multiplicative equations is discussed. A method for obtaining inverse transformations is described. The method presented may also be applied to parallelepipeds with free walls. Z. Kaczkowski, Poland

2240. Powell, A., On the approximation to the "infinite" solution by the method of normal modes for random vibrations, *J. Acoust. Soc. Amer.* **30**, 12, 1136–1139, Dec. 1958.

The "infinite" solution here is the response of a plane sheet to random pressures when the sheet is infinite in extent so that no reflections occur at boundaries. Paper indicates that infinite solution provides useful approximation to space average power spectrum of the response of a finite structure if (1) damping is not too small, (2) resolution of pressure field into wave number is smooth, and (3) the gravest modes are not excited. These conditions amount to the requirement that reflections should be negligible. It is shown, however, that if only the mean squared response (averaged in both time and space) is required then only condition (3) is required to justify the use of the infinite solution.

S. H. Crandall, USA

2241. Singh, B. R., and Nandeeswaraiya, N. S., Vibration analysis of turbine disc in its plane (in English), *J. Sci. Engng. Res., India* **1**, 2, 157–160, July 1957.

Starting with previously established equations of motion for turbine disk, the authors arrive at frequency equations for the circumferential and radial modes. Some numerical results are tabulated for different geometries, weight distributions, and hub constraints of the disks. F. T. Geyling, USA

2242. Rusanova, E. I., Discontinuous vibrations of the blades in axial compressors (in Russian), *Sudostroenie* no. 10, 21–24, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12356.

The dynamic stresses were measured in the basal sections of the working blades of the first three stages of an axial compressor. The vibrations of the blades took the nature of pulsations and were produced with a natural frequency; the maximum amplitude of the stresses increased with the decrease of the coefficient of air consumption through the compressor. Author explains the presence of vibrations as due to disruptive flutter which takes place at large angles of attack, when with increase in the angle of attack the coefficient of lifting force decreases. Formulas are put forward, with no previous deduction, which take into account the irregularity of the flow and the damping action in the blades' material, which formulas, so the author asserts, satisfactorily explain the observed phenomena. Author does not make use of the extensive data to be found in the literature regarding the question he is investigating and, in particular, makes no reference to the real occurrence of hysteresis of the lifting force, aerodynamical damping and rotating disruption. G. Yu. Stepanov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2243. Steinman, D. B., Modes and natural frequencies of suspension bridge oscillations, *J. Franklin Inst.* **268**, 3, 148–174, Sept. 1959.

Formulas for the natural frequencies of the potential vibration modes of suspension bridges are derived and assembled. Numerical examples are presented for the Mackinac Bridge and the effects of design changes are discussed.

B. Smilg, USA

2244. Palmov, V. A., Vibrations of rectilinear tubes containing a moving liquid (in Russian), *Nauchno-Tekhn. Inform. Byul. Leningrad Politekhn. In-ta* no. 12, 103–107, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 230.

The problem on the vibrations of a straight tube in which an evenly distributed liquid is flowing is solved with the aid of Laplace's conversion. The solution merges with the integration of a differential equation of the fourth order with constant coefficients. Four linearly independent solutions of the basic equation are obtained. As an example a case is solved when the tube is suddenly subjected to a constant concentrated moment. Formulas are obtained for the transpositions and equations for the frequencies, but the roots for the latter are not given.

G. S. Migirenko

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Wave Motion and Impact in Solids

(See also Revs. 2174, 2197, 2233, 2293, 2524, 2629)

2245. Pinkney, H. F. L., Stress waves, Nat. Res. Counc., Canada, DME/NAE Quart. Bull. no. 3, 1–21, July/Sept. 1959.

The present article is written to familiarize the reader with a few basic concepts of stress waves. The two types of waves, dilatational and distortional, which are propagated in an elastic medium are discussed. The reflection of these waves at a free boundary is considered and some problems pertinent to seismology indicated. The elementary solutions for longitudinal and torsional waves in rods are derived and the problems, a suddenly applied axial force and longitudinal impact, are treated. Some uses of stress waves, such as determining explosive and impact force-time curves and measuring the physical properties of materials, are indicated. From author's summary

2246. Kalinina, R. V., The relation between the velocity of propagation of elastic waves and the relative elastic characteristics of rocks (in Russian), *Prikl. Geofizika* no. 19, 216–229, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 868.

The question is discussed: for what rocks is the coefficient of rebound of a steel ball off the rock surface a sufficiently accurate macroscopic characteristic of elasticity? Using Hertz' formula for co-impacting bodies and assuming that the radius of the periphery of the impression (impact) can be shown in the form of a linear function of the rebound coefficient, author obtains a relation between the velocities of the elastic waves and the diameter of the impression for different rocks. As noted in the paper, good convergence of the experimental data with the calculations is obtained for clays, clay-limestone mixtures and also for clay-sand mixtures of medium porosity (10–20%). For friable rock species (calcite gypsum, quartz) an analogons correlation could not be established. Analyzing the results obtained, author is able to de-

duce that for fine-grained, clayey-soil types the application of the method of elastic characteristics appears to be justified. On the other hand, for elastic coarse-grained types this method fails, inasmuch as the small dimensions of the impression are comparable with the individual grains of the soil-type, the destruction of which being in no way connected with the velocity of the elastic waves. A description is furnished of the experiments for the determination of the magnitudes of velocity of the elastic waves in test samples of steel, paraffin and other types, with the aid of piezo-crystalline transmitters. The results of the tests of these samples, which were in the form of bars and plates, confirm the known theoretical deduction that the velocity of elastic waves decreases sharply when the length of the wave reaches parity with the diameter of the sample. A. T. Spiridonov

Courtesy Referativnyi Zhurnal, USSR Translation, courtesy Ministry of Supply, England

2247. Kositskii, L. V., Resistance of wood to impact deflection (in Russian), *Sb. Trudi Mosk. Inzh.-Stroit. In-ta* no. 13, 121–139, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 1051.

A relation is established between the geometrical dimensions of the sample and the work expended in its destruction by impact deflection. An investigation was made regarding the influence of moisture and the direction of the annual rings in the wood sample on the relation obtained. From author's summary

Courtesy Referativnyi Zhurnal, USSR Translation, courtesy Ministry of Supply, England

2248. Rakhmatulin, Kh. A., On the propagation of elastic-plastic waves owing to combined loading, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22**, 6, 1079–1088, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The propagation of elastic-plastic stress waves is studied in impacting slabs that have a relative velocity directed in the planes of and not normal to the impacting faces. Approximate averaged solutions are obtained for the "compression-shear" impact of two free slabs. The problem of "compression-shear" impact of two slabs lying between rigid planes is solved exactly. The problem of the impact of a hollow cylinder rotating about its axis of symmetry, and having a forward velocity along this axis, upon another hollow cylinder is reduced to the first problem solved in this paper. M. I. Yarymovych, USA

2249. Morland, L. W., The propagation of plane irrotational waves through an elastoplastic medium, *Phil. Trans. Roy. Soc. Lond. (A)* **251**, 997, 341–383, June 1959.

Paper deals with unidirectional wave propagation, treating interactions between elastic and plastic waves. Stress-strain relation with linear elastic region and concave-upward plastic region is derived and used so that elastic wave velocity is uniform, and plastic wave velocity an increasing function of stress. Analytical solutions to interactions between different types of continuous wave are developed, on the basis of which author discusses breakdown of smooth plastic compression wave into shock wave as well as propagation conditions. It is shown that heat dissipation is proportional to the cube of strain jump. Its low value for moderate shock strength suggests that shock does not appreciably affect stress-strain relation, an assumption from which solution for unloading of plastic compression front by overtaking elastic wave, while shock formation is taking place, is derived. Numerical illustration of this solution for a particular pulse in aluminum is given. K. Kasahara, Japan

2250. DiMaggio, F. L., and Bleich, H. H., An application of a dynamic reciprocal theorem, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 678–679 (Brief Notes), Dec. 1959.

Although the Betti-Maxwell reciprocal theorem of statics is familiar and often used, the existence of a similar theorem in dynamics does not appear to be as well known. In this note, the theorem is stated and an application to a wave-propagation problem is discussed. From authors' summary

Soil Mechanics: Fundamental

(See also Revs. 2186, 2643, 2644, 2651)

2251. Maasland, M., and Kirkham, D., Measurement of the permeability of tri-axially anisotropic soil, *Proc. Amer. Soc. Civ. Engrs.* **85**, SM 3 (*J. Soil Mech. Foundations Div.*), 25–34, June 1959.

Using analytical approach with transformed co-ordinates, authors solve flow equation for an ellipsoidal cavity, approximating cylindrical tip of a piezometer. "Shape Factors" are derived for length-diameter ratios of tips from 4 to 40 and for horizontal permeability ratios from 1 to 25. They show that for practical purposes change in horizontal permeability ratio is unimportant. T. A. Farrent, South Australia

2252. Szechy, K., The Varga-Makkai freezing sampler (in Hungarian), *Melyepitestudomanyi Szemle* **9**, 2, 70–71, Feb. 1959.

2253. Tsvylev, N. A., Strength of rocks (in Russian), *Trudi Novocherk. Politekhn. In-ta* **52/66**, 64–83, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 870.

Soil Mechanics: Applied

(See Revs. 2186, 2333, 2527, 2528, 2651)

Processing of Metals and Other Materials

(See also Rev. 2298)

2254. Kobayashi, S., Herzog, R., Lapsley, J. T., Jr., and Thomsen, E. G., Theory and experiment of press forging axisymmetric parts of aluminum and lead, *ASME Trans.* **81**B (*J. Engng. Indust.*), 3, 228–238, Aug. 1959.

Simplified analysis of closed-die forging based on homogeneous compression of a disk of flash thickness between rough, rigid plates. Coulomb friction is assumed to act over the annular periphery (flash area proper) and plastic shear between the fictitious central portion of the "disk" and the bulk of the slug.

Experiments on lead and aluminum lend limited support to the usability of the resulting force formulas. N. H. Polakowski, USA

2255. Chekmarev, A. P., Dinnik, A. A., and Grechko, V. P., The deformability of steel when being rolled at great area reduction (in Russian), Rolling and tube-making industries, Moscow, Metallurgizdat, 1958, 75–92; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 815.

Questions are investigated regarding the plasticity of the metal during rolling with heavy compression, with the angle of engagement greater than the angle of friction ($\alpha > \beta$). The theoretical analysis of the distribution of the basic and supplementary stresses in conditions of complete forging of the strip showed that in the entry portion of the seat of deformation over the whole width of the strip and on the margins of the free expansion a mixed scheme of stresses with longitudinal tension stresses is in operation. The remaining parts of the strip deform in conditions of un-

even volumetric compression. On the basis of the hypothesis of normal stresses the disruption of the continuity of the metal when rolling at angles $\alpha > \beta$ is possible at the entry of the strip to the rollers on the margins of free expansion. This is experimentally confirmed by blooming-mill-rolling of rail steel with notches. The regime of compression indicating effect on the scheme of the stressed state influences its plastic stability in the same way. The less plastic metal shows great sensitivity to the different regimes of compression; the more plastic, the reverse. Absence of traces of hair cracks on the contact surface of the strip and the lateral margins provides evidence of the fact that, in conditions of great compression in rolling at angles $\alpha > \beta$, with preliminary heating of the metal the hair cracks do not appear to be loci of sag. With compression of the order of 75% the limits of plasticity of rolled steel of low or medium carbon content are not exceeded. Consequently the tensile stresses on the lateral margins for these steels are not dangerous. I. A. Razov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2256. Beresnev, B. I., Vereshchagin, L. F., and Riabinin, Iu. N., On the effect of hydrostatic pressure on the change in the mechanical properties of aluminum after large plastic deformations (in Russian), *Fiz. Met. i Metall.* **7**, 1, 128–132, 1959. (Translated by Morris D. Friedman, P. O. Box 35, W. Newton, Mass. B-141, 6 pp.)

Samples of aluminum of grade AD1 were extruded under hydrostatic pressures up to 100,000 psi. The area reduction achieved by extrusion ranged from 70.4% to 95%. Simple tension tests were then conducted to determine the changes in the mechanical properties of the samples. It was noted that the tensile strength increased as the area reduction increased for the samples so extruded. For the same area reduction, the intensity of the pressure at which extrusion took place appeared to have no effect on the tensile strength. However, it was reported that for the same area reduction by extrusion, the uniform elongation and the strain at fracture increased linearly with the pressure. L.-W. Hu, USA

2257. Thunell, B., Determination of cutting forces in woodworking (in German), *Holz Rob- Werkstoff* **16**, 4, 138–145, Apr. 1958.

Paper is concerned with intermittent processes, principally sawing and milling. Experimental part of paper is concerned with practical tests and laboratory experiments with a specially-designed double pendulum dynamometer and a simplified milling rig. Practical tests were at cutting speeds ranging from 12–90 fps, with sharp and worn cutters. Laboratory experiments were conducted to investigate the effects of lack of isotropy on cutting forces, materials tested being beech, pine and birch.

Analytical part of paper attempts to allow for the obscuring effect of initial impact force on the measured or apparent force. An extensive bibliography is given. R. C. Brewer, England

2258. Okushima, K., and Fujii, Y., On ceramic cutting tools, in the case of machining carbon steel, *Bull. JSME* **2**, 6, 217–223, May 1959.

Comprehensive results are given for machining 0.4% carbon steel with ceramic tools. Influence on tool life of physical properties of ceramic, cutting conditions and tool angles are investigated. Wear and failure are compared with that of carbide tools.

R. N. Arnold, Scotland

Fracture (Including Fatigue)

(See also Revs. 2276, 2291)

2259. Rolfe, S. T., Hall, W. J., and Newmark, N. M., Brittle-fracture tests of steel plates containing residual compressive strain, *Welding J.* **38**, 4, 169-s–175-s, Apr. 1959.

Author shows that the propagation of a brittle fracture is retarded by a residual compressive-strain field and even arrested with higher strain levels. In the test specimens (steel plates 3/4 in. thick, 2 ft wide and 5 ft long) compressive residual strains in the central parts were induced by means of heat treatments at the edges or arc welding tapered slots perpendicular to the edges. Residual strains were measured with mechanical and wire-electrical strain gages. The cracks were initiated by driving a wedge into a notch at the edge of the plate, which was in a field of tensile residual strain. The compressive strains in the central part were adjusted by superimposing a suitable tensile load on the plate.

With compressive strains of 150.10^{-6} in./in. the fracture speed decreased to about 350 fps and with strains of $650–750.10^{-6}$ in./in. the fracture was arrested in the compressive region. Conclusion: it seems feasible to arrest brittle fractures in composite structures by suitable prestressing to induce regions of compressive strain.

R. G. Boiten, Holland

2260. Weil, N. A., Rupture characteristics of safety diaphragms, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 621–624, Dec. 1959.

Previous analyses by R. Hill and by the author are combined to give a convenient approximate theory of the instability rupture of circular pressure safety disks, assuming stress to be a simple power of logarithmic strain. Critical deflections are given with some accuracy by the present approximation, but bursting pressures are given more accurately by the author's previous approximation. The condition for reliable operation is that plastic instability should be reached before fracture.

F. R. N. Nabarro, England

2261. Bartenev, G. M., and Polik, B. M., Pecularities of fracture of glass, subjected to internal stresses (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 10, 141–143, Oct. 1958.

2262. Frankland, J. M., Triaxial tension at the head of a rapidly running crack in a plate, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 570–572, Dec. 1959.

Paper shows, from a theoretical analysis, that appreciable normal stress through the thickness of a plate can occur when a crack is growing rapidly in contradistinction to the usual assumption that the condition near a stationary or growing crack is a state of plane stress. The amount of triaxiality is strongly dependent on the extent of the plastically deformed dimple zone at the head of the crack, which may be one reason for the greater apparent brittleness shown by thick plates. As this depression moves through the plate ahead of the crack it must give rise to accelerations which produce a tensile stress normal to the plate surface, and with crack propagation speeds of up to 6000 fps, this acceleration could be large. As the real test of the author's theory must be experimental, it is suggested that observers of the behavior of rapidly growing cracks give more attention to the extent and form of the plastically deformed region at the head.

A. F. W. Langford, Australia

2263. Thomas, T. Y., Fracture of circular pipes by internal pressure, *J. Math. Mech.* **8**, 5, 623–641, Sept. 1959.

Two-thirds of paper is taken up in arriving at some elementary results of elastoplastic stress analysis, allowing almost every possible idealization: no work-hardening, Tresca's yield condition, von Mises plasticity equations, small strains, and incompressible material. Remaining third is introduced as follows: "Denote by Σ the intersection of the pipe with a half-plane through its central axis. It will be shown that Σ is a surface of strong instability in

the plastically deformed pipe .... Specifically this means that, if actual plastic flow is initiated on one side of the plane Σ in the plastically deformed pipe, the velocity, at points of Σ, will necessarily become indefinitely large within a finite time. Hence the pipe will be subject to fracture over the plane Σ ...." No proof is given that Σ exists. In any case reviewer cannot follow the subsequent argument, nor is its soundness proved by the fact "that fracture may occur in the pipe over the plane Σ is confirmed by laboratory tests." In view of the heavy tensor formalism employed (and which seems unnecessary), only an engineer of exceptional mathematical background could find the paper readable.

M. A. Jaswon, England

2264. Fastov, N. S., Influence of surface energy on the field of elastic stresses near macro-defects in the structure of solid bodies (in Russian), Sb. *Trudi* In-ta Metalloved. i Fiz. Metallov Tsentr. n.-i In-ta Chernoi Metallurgii **5**, 600–603, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 689.

Author deduces the boundary conditions for the stresses when it is essential to take into account the surface energy, basing his deductions on the fact that during elastic isothermal equilibrium and arbitrary variations in the displacements the change of free energy is equal to the work done by external forces above the body.

G. S. Shapiro

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2265. Serensen, S. V., Kogaev, V. P., Stepnov, M. N., and Giatsintov, E. V., Regarding the distribution of durability during fatigue tests, *Indust. Lab.* **24**, 3, 363–367, May 1959. (Translation of *Zavod. Lab., SSSR* **24**, 3, Mar. 1958 by Instrument Soc. Amer., Pittsburgh, 22, Pa.)

Rotating-beam tests using smooth, polished specimens of aluminum alloy termed V 95 ($\sigma_B = 58.0$ kg/mm^2) were conducted at stress levels 30, 24, and 21 kg/mm^2 (50, 20, and 5% higher than estimated fatigue limit) and speed 6000 rpm. Some 20 specimens were run at each level. Plotting $\log N_m$ vs. $m/(n+1)$, straight lines were obtained for 30 and 24 levels, while for 21 level a lower bound (threshold sensitivity) $N_{0,S} = 6.10^5$ was observed as estimated by graphical rectification of the $\log (N - N_{0,S})$ vs. $m/(n+1)$ curve.

Since values $N_{0,S} = 0$ for higher levels were believed to be a consequence of too small sample sizes, 463 specimens were tested at 30 level, resulting in an estimated value $N_{0,S} = 2.10^4$ cycles. Agreement achieved between observations and assumption that $\log (N - N_{0,S})$ be normally distributed was very satisfactory, proving this assumption to be workable. Its advantage is—quite correctly—stated to be easiness of setting confidence limits, as demonstrated by indicated 90% regions.

W. Weibull, Sweden

2266. Yokobori, T., A study of the nature of fatigue damage of plain carbon steel by reheating method, *Technol. Rep. Toboku Univ.* **23**, 2, 91–101, 1959.

An attempt was made to study the relation between a true fatigue damage established by Sinclair and Dolan's experiment and so-called fatigue damage determined by French method, in which the damage is measured by the decrease of the original endurance limit. Work-hardening induced in unnotched and notched specimens during cyclic stressing was removed by reheating. Since the specimens subjected to this processing could not survive over 10^7 cycles, it may be concluded that so-called fatigue damage as determined by French method can not be repaired by such annealing even at early stages in fatigue life.

A few exploratory tests with notched specimens showed that the fatigue damage was repaired by understressing, but the improvement due to understressing was lost by subsequent reheating for stress relief.

From author's summary

2267. Moskvitin, V. V., Statical elasto-plastic deformations for repeated cyclic loading (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 24–32, July 1958.

Author made an attempt to develop equations of stress-strain relationship under a number of load cycles. He stressed that a cyclic loading of an elastoplastic material does not necessarily involve internal stresses of a cyclic character. Critical loads were determined, and a few examples of stress distribution discussed.

M. G. Bekker, USA

2268. Walker, P. B., Fretting in the light of aircraft experience, *J. Roy. Aero. Soc.* **63**, 581, 293–298, May 1959.

Qualitative discussion of fretting in relation to fatigue failure of joints provides a rather complete picture, although admittedly hypothetical in several particulars. A useful review.

H. J. Grover, USA

Experimental Stress Analysis

(See also Revs. 2220, 2259, 2262, 2275, 2276, 2528)

2269. Gaymann, T., Stress analysis of shells by the photoelastic frozen stress technique (in German), *VDI Forschungsheft* **25**, 471, 36 pp., 1959.

This paper is an almost complete reproduction of a thesis which was presented by the author in 1957 at the Institute of Technology of Munich. After a brief introduction (1.), he first investigates in detail the photoelastic properties of Araldite B, a transparent artificial resin, which is becoming more and more the standard material for three-dimensional photoelasticity (2.). In the next part (3.) he presents different special procedures concerning the order of magnitude of certain errors involved by using the freezing method with Araldite B for shells. These errors are due to the fact that it is practically impossible to realize a perfect mechanical similarity from model to prototype. In the following three sections, author describes applications of this method. The first one (4.) concerns the state of stress in a cylindrical circular shell under the action of external load uniformly distributed along a normal section. In the second application (5.), an analogous shell is investigated, but under the action of two external isolated forces which are equal and applied at opposite ends of a diameter. The third one (6.) concerns the determination of the stresses in the two parts of a pipe bifurcation under the action of a constant internal pressure. The main tube and the branch are circular cylinders with axes intersecting at an angle of 90°. In part (7.), author gives a summary of the main conclusions from his experiences. In the last part (8.), he gives a few suggestions for the preparation of Araldite B and on the tests involving the weight of a structure.

The tests described in this paper have been made carefully and the conclusions are interesting. The reviewer believes an important fact to point out is that the author was able to measure, with a relatively good precision, the fringe order of the birefringence using models of Araldite which had a thickness of only 1/8 to 3/16 inches.

H. Favre, Switzerland

2270. Ades, C. S., Reduction of strain rosettes in the plastic range, *J. Aero/Space Sci.* **26**, 6, 392–393 (Readers' Forum), June 1959.

2271. Bertodo, R., Development of high-temperature strain gauges, Instn. Mech. Engrs., Prepr., 14 pp., 1958.

2272. Keast, D. N., Calibration of accelerometers in a simulated space environment, *J. Acoust. Soc. Amer.* **31**, 5, 584–587, May 1959.

For the purpose of measuring the properties of cushioning materials under simulated space conditions, it has been necessary to calibrate accelerometers for use in this unusual environment. Calibrations over the temperature range from −320 F to +80 F, and at an atmospheric pressure of 5×10^{-9} mm Hg, are reported for several different types of barium titanate accelerometers. These calibrations were obtained at several frequencies between 20 cps and 100 cps by the optical viewing method.

From author's summary

2273. Kilpi, J., Concerning the influence of out-of-roundness of a pressure vessel, of a cellulose digester in particular, on stresses and distortions, Parts I and II (in German), *Z VDI* **101**, 11, 421–429, Apr. 1959; **101**, 14, 568–573, May 1959.

Strain and deflection measurements are reported on pressure vessels having small deviations from circular form. Results are compared with theoretical values, based on assumption that form of the cross section may be expressed either by Fourier series or by a simpler trigonometric relation. Tests are also reported on circular ring under radial loading and having an initial hump or bulge representing deviation from circular form. Theoretical and experimental results on latter show good agreement. On basis of results, suggestions are made regarding permissible out-of-roundness in pressure vessels.

A. M. Wahl, USA

2274. Annaratone, D., Test of boiler shell and collecting pipes with compensated holes (in Italian), *Termotecbnica* **13**, 4, 169–172, Apr. 1959.

Material Test Techniques

(See also Revs. 2259, 2285, 2297, 2528)

2275. Hondros, G., The evaluation of Poisson's ratio and the modulus of materials of a low tensile resistance by the Brazilian (indirect tensile) test with particular reference to concrete, *Austral. J. Appl. Sci.* **10**, 3, 243–268, Sept. 1959.

The Brazilian or indirect tensile test is a convenient and established technique for the assessment of the tensile strength of concrete, a material which, because of its low tensile resistance, presents testing difficulties with which conventional methods cannot cope. This paper describes, inter alia, the analysis of the circular specimen loaded to conform to the accepted practical recommendations for the Brazilian test, and its extension to yield a direct method for evaluating Poisson's ratio and Young's modulus of cement mortars and concrete. Steel specimens were employed to assess the validity of the experimental techniques and to select an acceptable specimen shape for use in destructive tests on concrete.

From author's summary by F. Garofalo, USA

2276. Padfield, Daphne G., and Dickinson, Nora B., Stresses and strains in an infinite elastic sheet under a tension applied at two rigid pairs of square jaws, *Brit. J. Appl. Phys.* **9**, 11, 448–452, Nov. 1958.

Two common tensile tests of fabrics are made with the specimens either in the shape of a strip (strip tensile test), or in the shape of a sheet (grab tensile test). In the first the jaws of the testing machine are as wide as the specimen, while in the second the specimen is much wider than the jaws. Authors have attempted to approximately determine the stresses in these two tests by superposition of several point forces at strategic positions along the edges of the jaws together with assumed strain conditions. The solution of the stresses in an infinite plate subjected to a point load was applied for the stresses in the grab test and a polynominal stress function was added to solve for the stresses in the strip test.

The stresses are determined both analytically (the solution is well suited to an electronic computer) and by relaxation methods. Several Poisson ratios are used. As the paper is mainly of value to those interested in fabrics, reviewer believes authors should have compared the stresses in the two tests instead of discussing the accuracy of the two methods of solution.

N. C. Costakos, USA

2277. Goliamina, I. P., and Romanenko, E. V., An arrangement for determining the elastic constants of solid bodies, *Instruments and Experimental Techniques* no. 5, 683–687, July 1959. (Translation of *Pribory i Tekbnika Eksperimenta, USSR* no. 5, 90–94, Sept./Oct. 1958 by Instrument Society of America, Pittsburgh, Pa.)

The design of equipment for determining the elastic constants of solid bodies is described.

The method is based on the measurement of the characteristic vibrations of cylindrical rods made of the material being tested; the phenomenon of dispersion of longitudinal waves in rods is used to measure Poisson's ratio. The accuracy of measurement of Young's modulus is not less than 2%, and of Poisson's ratio, ~3%. For magnetic materials, the equipment permits determination of the dependence of elastic parameters on the value of a constant magnetic field.

From authors' summary

2278. Kula, E. B., and Larson, F. R., Effect of specimen taper on determination of elongation in the tension test, *ASTM Bull.* no. 238, 58–61, May 1959.

In the ASTM standards for round tension specimens, a 1 per cent difference in diameter is permitted between the center and ends of the gage length section. This difference in original diameter at these two points is found to lead to differences in local strain of over 30 per cent. Two models for the shape of a tension specimen are assumed, and the effect of the difference in strain between the center and end of the gage length section on total elongation is calculated. Standard ASTM specimens of titanium, iron, and copper were prepared and, in agreement with the calculated results, showed measured elongation as much as 15 per cent less than specimens having a uniform diameter throughout the gage length section. Since the reduced diameter at the center of the gage length section is necessary to insure that fracture occurs in the center of the specimen, the differences inherent in determination of elongation from such specimens should be recognized. More widespread use of diameter gages is suggested.

From authors' summary

2279. Tsobkallo, S. O., and Vashchenko, Z. A., Comparison of the static load and subsonic methods of determining the modulus of elasticity of sheet materials, *Indust. Lab.* **24**, 1, 66–68, Feb. 1959. (Translation of *Zavod. Lab., SSSR* **24**, 1, 68–70, Jan. 1958 by Instrument Society of America, Pittsburgh, Pa.)

A new subsonic method for determining the modulus of elasticity of flexible sheet materials eliminates systematic errors and possesses a higher degree of accuracy than the static method.

From authors' summary

2280. Burago, A. N., A new method of recording the velocity and the dynamic deflection of the working parts of impact-testing plants, *Indust. Lab.* **24**, 3, 379–382, May 1959. (Translation of *Zavod. Lab., SSSR* **24**, 3, 338–342, Mar. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2281. Markovets, M. P., and Trot'iakov, V. P., Method of abrasion testing at high temperatures, *Indust. Lab.* **24**, 5, 704–705, June 1959. (Translation of *Zavod. Lab., SSSR* **24**, 5, 625–627, May 1958 by Instrument Society of America, Pittsburgh, Pa.)

2282. Drozd, M. S., The new hardness number and the mechanical properties of steel, *Indust. Lab.* **24,** 8, 1117–1123, Sept. 1959. (Translation of *Zavod. Lab., SSSR* **24,** 8, 1002–1007, Aug. 1958 by Instrument Society of America, Pittsburgh, Pa.)

In a previous paper, not available to reviewer, author described a new ball-type hardness test. Using a relation between the new hardness number and the load at which impression is produced, as developed in previous paper, author relates, for various steels, the new hardness number to yield strength, tensile strength, and to the complete flow curve, with apparent good agreement.

G. V. Smith, USA

2283. Bergh, S., Josefsson, A., and Lagerberg, G., Apparatus for creep testing at ambient temperatures (in Swedish), *Jernkontorets Ann.* **143,** 10, 694–697, 1959.

2284. Takaoki, A., Ultrasonic testing of heavy steel forgings. I, Reflection from simulated discontinuity in water, *Bull. JSME* **2,** 6, 252–257, May 1959.

As a fundamental experiment of ultrasonic techniques to be applied to the nondestructive testing of heavy steel forgings, ultrasonic reflection from simulated discontinuities and bottom surfaces were studied in water. Equivalent reflection surfaces of three each simulated discontinuities and bottoms were investigated and the nomograms for the size of discontinuities were established from the ratio of flaw-to-bottom indications and the distances from the transducer to them.

The results obtained will not be applied immediately for heavy steel forgings but will be of future value and aid for analysis of reflection phenomena in steel and for the compilation of inspection data. From author's summary

Properties of Engineering Materials

(See also Revs. 2247, 2256, 2258, 2267, 2276, 2282, 2298, 2305, 2504, 2663)

2285. Natapov, B. S., and Fal'kevich, E. S., On the determination of the mechanical properties of steel for deep drawing from the values of the coercive force, *Indust. Lab.* **24,** 8, 1130–1131, Sept. 1959. (Translation of *Zavod. Lab., SSSR* **24,** 8, 1013–1015, Aug. 1958 by Instrument Society of America, Pittsburgh, Pa.)

The possibilities of obtaining yield point and hardness values of a low-carbon steel sheet by measurement of the coercive force are investigated. A close correlation between the variables was obtained and authors suggest that this method is more reliable than normal hardness measurements on thin sheet.

F. Ellis, England

2286. Razov, I. A., and Shevandin, E. M., Use of grids for the study of the effect of various forms of stresses on the plastic limit of steel, *Indust. Lab.* **24,** 3, 357–362, May 1959. (Translation of *Zavod. Lab., SSSR* **24,** 3, 317–324, Mar. 1958 by Instrument Society of America, Pittsburgh, Pa.)

For flat, unnotched specimens of different widths, and specimens $20 \times 20 \times 110$ mm in size and with notches of different shapes in bending it was established that the maximum critical strain, corresponding to both the beginning and the end of fracture, decreases as the intensity of the stress increases. The maximum true shear also decreases and this indicates that the stress, which forms in the surface layer of the specimen and is due to the localization of deformations in individual groups of grains and to the formation of "localized necks," is volumetric. The extent to which the stress is volumetric increases when the width b of the specimen is increased and the radius ρ of the base of the notch is decreased and approaches a critical value at definite values of b and ρ. The critical width of a smooth specimen is equal to five times its thickness, and the critical radius of the base of the notch is equal to $b_n/20$, where b_n is the width in mm of a notched specimen with a square cross section. The critical volume stress for smooth and notched specimens is the same and is described by the following values of the main stresses: S_1, $S_2 = 0.5S_1$, and $S_3 = 0.35S_1$. The maximum true shear cannot be used as a criterion of plasticity because it is determined by two main stresses S_1 and S_3 only.

During stretching of wide flat specimens a planar stress is actually formed and, as the width of the specimen increases, the stress S_2, perpendicular to the surface, increases and the critical plasticity of the material decreases.

From authors' summary

2287. Obozov, I. P., and Shevelev, V. V., The significance of the relative dimensions of the transverse section of a plane sample in the evaluation of the plastic properties of steel of low carbon content (in Russian), *Zavod. Lab.* **24,** 1, 84–85, 1958; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 13503.

The influence is investigated experimentally of the relation of the sides of a rectangular section of a sample of steel of low carbon content on the relative residual elongation δ and the relative constriction ψ_k during fracture. The relation of the sides of the section b/a varied from 1 to 8. The linear bond between ψ_k and the relation b/a was found. D. D. Akimov-Pereets

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2288. Finkel'shtein, B. N., and Usova, L. F., Investigation of the aging of technical iron by the method of internal friction (in Russian), *Sb. Mosk. In-ta Stali* **36,** 176–190, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 13559.

The process of aging of technical iron was investigated; three sorts of iron were concerned, with different chemical compositions, after quenching and other forms of heat treatment. The method adopted for the investigation was the indirect method, based on the sensitivity of the process of aging to the internal dissipation of energy in the material during vibration. In addition, an investigation was made of the influence of aging on the modulus of normal elasticity E and the modulus of shear G. It was established that E and G for the materials being investigated did not vary in the process of aging, allowance being made for the margin of experimental error. V. V. Khil'chevskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2289. Frost, N. E., A relation between the critical alternating propagation stress and crack length for mild steel, Instn. Mech. Engrs., Prepr., 1959, 19 pp.

Fatigue tests have been carried out on mild steel specimens containing edge cracks of various lengths, and the alternating stress just insufficient to cause the cracks to grow obtained. It was found that the relation between this critical alternating stress σ and the crack length l was given by $\sigma^3 l$ = constant. By means of this relation it was possible to correlate a wide variety of hitherto unrelated notch fatigue data. From author's summary

2290. Swindeman, R. W., and Douglas, D. A., Improvement of the high-temperature strength properties of reactor materials after fabrication, *J. Nuclear Materials* **1,** 1, 49–57, Apr. 1959.

Possibilities are reviewed for improving the high-temperature strength properties of three nickel-base alloys after fabrication of sheet material. Creep and tensile data are presented for Inconel, Hastelloy B, and INOR-8. Depending on the material and service conditions, improvements in strength can be brought about by any of three treatments: (1) annealing or aging, (2) carburization, and (3) environmental control during service.

Data showing the relative strengthening by each of these means are presented. Carburization produces the greatest increase in creep strength. From authors' summary

2291. Zhukov, A. M., Concerning the failure conditions of plastic metals in a complex state of stress (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 5, 110–112, May 1958.

From an analysis of published data of experiments with isotropic metals, author concludes that the Guber-Mises conditions of plastic deformation are in good agreement with the experiments. According to the author's own experiments, conducted with anisotropic metals such as aluminum alloy D-16-T and magnesium alloy MA2 manufactured in the form of rods, satisfactory agreement with the experiments, in which the specimens were subjected to bi-axial tension in the directions of the principal axes of anisotropy, gives the following conditions of plasticity:

$$\sigma_1 = \sigma_{1s} \quad \text{when} \quad \sigma_1/\sigma_{1s} > \sigma_2/\sigma_{2s} > 0$$

$$\sigma_2 = \sigma_{2s} \quad \text{when} \quad \sigma_2/\sigma_{2s} > \sigma_1/\sigma_{1s} > 0$$

The author then describes a number of experimental investigations, including his own, in which the tubular specimens of aluminum alloys, magnesium alloys, and steel were tested under bi-axial tension. He describes in detail the investigations made by L. W. Hu [*J. Mech. Phys. Solids* **4**, no. 2, 1956; AMR **9**(1956), Rev. 2931], in which the tubular specimens of aluminum alloy 61S-T6 were tested. These specimens were subjected to internal and external pressure and, by varying P_1 and P_2, the different stress conditions in the walls of the specimens were achieved. Using the data given by Hu, author determined all three principal stresses and the maximum shear stresses. From the evidence of all the experimental data used by the author, he concludes that the failure of plastic metals in a complex state of stress is in good agreement with the maximum-shear theory.

A list of 12 references is presented at the end of the article.

E. I. Radzimovsky, USA

2292. Bobylev, A. V., and Chipizhenko, A. I., The connection between the depth of the impression by the Ericksen test and the mechanical properties of brass (in Russian), *Trudi Gos. N.-i. Proektn. In-ta po Obrabotke Tsvetn. Met.* no. 17, 19–33, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 13546.

The question is investigated of the proper control of sheet materials in regard to their capacity for pressing by the Ericksen method. The material used in the investigation was brass, marks L62 and L68 in the form of ribbons 0.1 to 2 mm thick. Mechanical tests were carried out (for fracture, depth of impression by the Ericksen method, hardness, bending and double bending). It was shown that the Ericksen method is inaccurate and should be replaced by the method of twisting and tensioning.

V. M. Kardonskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2293. Ionaitis, S., On the determination of the impact splitting resistance of wood in the direction of the grain, *Indust. Lab.* **24,** 1, 88–90, Feb. 1959. (Translation of *Zavod. Lab., SSSR* **24,** 1, 89–90, Jan. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2294. Snodgrass, J. D., Statistical approach to working stresses for lumber, *Proc. Amer. Soc. Civ. Engrs.* **85** ST2, (*J. Struct. Div.*), 9–43, *Feb.* 1959.

2295. Lonnov, V. G., Investigation of the strength and deformability of pine wood under the action of a prolonged load, applicable to calculations of the components of wooden constructions (in Russian), *Trudi Gorkovsk. Inzh.-Stroit. In-ta* no. 27, 65–122, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 1053.

Tests to destruction were carried out, with gradually increasing loads, by tension and compression of large samples of pine along the grain, of beams for transverse deflection and bars for compression. This was done to obtain diagrams to show the lower limits for tension and compression and to verify the calculation equations, taking into account the effect of prolonged loading. The loading was carried out up to the damping of the deformations' aftereffect at each step, with measurements for the same at determined intervals of time. For comparison, the usual (short-time) tests were also carried out, with measurement of the deformations. Values were found for the moduli of momentary elastic deformation and the moduli of deformations of elastic aftereffects on the scale of relative stresses. An equation was obtained for the deformation of the aftereffect in relation to the time at each step in the loading Formulas are proposed for the calculations of wooden joists when subjected to deflection, compression and compression with deflection. The formulas obtained are used in the calculations for a sectional network arch built of bent girders and in the calculations of its branches, taking into account the prolonged action of the load.

A. S. Dvornichenko

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2296. Sheppard, H. R., and Ginsburg, H., Should statistical methods be used to prepare materials specifications, *ASTM Bull.* no. 236, 31–34, Feb. 1959.

2297. Anthony, F. M., and Pearl, H. A., Selection of materials for hypersonic leading-edge applications, *Aero/Space Engng.* **18,** 7, 40–43, 62, July 1959.

Structures: Simple

(See also Revs. 2199, 2216, 2217, 2226, 2229, 2268, 2295, 2308, 2309)

Book—2298. Conference on metallurgical and engineering aspects of weight-saving in steel structures, Session 1958/59; Journal of the West of Scotland Iron and Steel Institute, Vol. 66; Glasgow, West of Scotland Iron and Steel Institute, 1958, viii + 197 pp. $6.80.

Book contains different lectures delivered at the conference and gives a comprehensive summary of all the practical and theoretical efforts referring to weight-saving of steel structures. The study by M. R. Horne and T. M. Charlton deals with the influences of the approximations of the theory on the results of calculations. G. B. Godfrey shows the different applications of tubes to steel structures. In his opinion, there is an extensive not entirely explored possibility for the application of tubular constructions. A weight-saving of from 30 to 50% may be achieved by the suitable use of tubes. R. M. Kenedi discusses the different employment of cold-formed sections, whereas W. G. Kirkland gives a view of cold-forming practice in the U.S.A. They state that the application of cold-formed sections could bring about a substantial reduction in both the weight and operating costs. For this, and because of the continuous development in manufacturing procedures, a widespread, rapid growth is to be expected in the use of cold-formed sections. An essential weight-saving can also be attained by using high-tensile steels. This question is briefly discussed by I. M. Mackenzie, A. E. Long and G. Roberts. These, as well as the other lectures and the discussions, give a good survey on the importance of continually developing both the quality of the designs and the manufacturing methods of steel structures.

P. Csonka, Hungary

Book—2299. Goryunov, B. F., Redundant constructions of prestressed ferroconcrete (in Russian), Leningrad-Moscow, Gos. Izdvo Lit. po Str-vu i Arkhitekture, 1957, 207 pp. 7r., 10k; *Ref. Zh. Mekh.* no. 10, 1958, Rev. 11802.

The basic state of affairs in connection with the designing and calculations of prestressed reinforced redundant constructions (in concrete) is surveyed, covering continuous beams, frames, plates and shells. The most attention is devoted to continuous beams. Based on an analysis of the results of experiments by Magnel [G. Magnel, "Le beton precontraint," 1953], Guyon [I. Guyon, "Le beton precontraint," 1952] and Lin [T. I. Lin, *J. Amer. Concrete Inst.* **24**, 7, 1953] recommendations are made that: the deflection moments along the length of the beam up to the appearance of cracks be calculated by the elastic stage, and the moments producing the cracks—taking into account the plastic deformations, which limit the loading—by taking into account the complete redistribution of the moments along the length of the beam; but in all cases, where today there is not in existence a worked-out scheme for the consideration of the redistribution of moments, it is permissible to determine the magnitude of the deflection moments by the elastic stage. These conclusions also apply to other types of redundant constructions made with prestressed ferroconcrete. Formulas are advanced and examples given for the calculations of redundant beams of prestressed ferroconcrete by the elastic stage, using the method of forces, the method of angular deformations and the combined method. In order to evaluate the magnitudes of the forces, which are developed by shrinkage and creep, the results of the calculations for a double-span beam are furnished. For the calculations for the boundary state A. A. Gvozdev's method ["Calculations for the carrying capacity of a construction by means of the method of boundary equilibrium," Gosstroiizdat, 1939] is recommended. The different methods of calculation for frames by the elastic stage are investigated using an example of a two-hinged frame. On this example also is given an evaluation of the influence of shrinkage and creep, and an investigation carried out on the basic situation regarding the calculations for frames in accordance with their carrying capacity. Methods of calculation for rectangular plates by the elastic stage and numerical examples are given for cases of support on two, three and four sides. Resulting from the calculations made a recommendation is put forward to distribute the prestressed reinforcement between two mutually perpendicular directions in proportion to the moments due to external loading. A round plate is examined. Examples are provided of prestressed reinforced shells, of some concepts on the calculation of shells as bodies of rotation and calculations for cylindrical and spherical shells. At the beginning of the book general information is to be found and at the end, evaluations of the advantages accruing from the adoption of redundant constructions made of normal prestressed ferroconcrete as against similar constructions made of ordinary ferroconcrete (with 15–20% economy) and redundant constructions made of prestressed ferroconcrete (with a decrease of quantity of reinforcement of 20–30%).

G. M. Chuvikin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2300. Tassi, G., The theory of anchorage of prestressed reinforcement in concrete (in Hungarian), *Epites- es Kozlekedestudomanyi Kozlemenyek, Budapest* no. 1/2, 217–258, 1959.

The distribution of bond forces arising between steel and concrete is investigated in this paper. Starting from functions which are in good agreement with experience, author develops a general theory. From this, formulas are obtained, suitable for computing the bond forces in question. The theories of other authors are also recapitulated and criticized.

From author's summary

2301. Ratts, E. G., Kholinyanskii, M. M., and Kol'ner, V. M., Studies of bonding in reinforced concrete (in Russian), *Beton i Zhelezobeton* no. 1, 4–13, 1958; *Ref. Zh. Mekh.* no. 10, 1958, Rev. 11789.

Descriptions are given of the results of theoretical and practical studies on the bonding of wires to concrete. The tests showed that: (1) the bonding is due essentially to the stability of the concrete; (2) the imparting to the wire of a periodical profile improves its bonding to the concrete to a greater degree than the decrease of the wire's diameter; (3) fundamentally the bonding depends on the depth of the hollows. The results of the tests and the theoretical investigations enabled recommendations to be made for the determination of the length of the anchorage zone for a wire of periodic profile.

A. S. Kozhevnikov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2302. Hangan, M., A method for calculating hyperstatic structures in the plastic range through successive approximations (in Roumanian), *Studii Si Cercetari Mecan. Appl.* **10**, 3, 795–817, 1959.

Author chooses as unknowns of the problem the ratios of the elastic moments, multiplied by a safety coefficient, to the plastic moments in the same cross section. These ratios decrease successively, and paper gives the order in which the plastic hinges occur.

Three examples of application are included.

P. P. Teodorescu, Roumania

2303. Petcu, V., On the solving of elastic equilibrium equations with Jacoby-type matrix (in Roumanian), *Studii Si Cercetari Mecan. Appl.* **10**, 3, 855–865, 1959.

A recurrent solution is given for equations whose matrix is characterized by: (1) equality of all coefficients which are not situated on the main diagonal, and (2) equality of the coefficients situated on the main diagonal, except the coefficients situated at the diagonal ends, which may differ. Such equations are frequently met with in the theory of structures.

An example of application is presented.

P. P. Teodorescu, Roumania

2304. Barta, J., Four moments equation for the stress analysis of plain structures of one dimension (in German), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **26**, 1/2, 79–85, 1959.

The equation is derived which is fulfilled by the four bending moments of the structure. This equation is applied for solving the following problems: to compute the buckling load of a hinged bar polygon; to generalize the bending moment equation of the straight bar for the case of the curved bar; to express the differential equation of the funicular curve in natural coordinates.

From author's summary

2305. Sidebottom, O. M., and Clark, M. E., Theoretical and experimental analysis of members loaded eccentrically and inelastically, Ill. Engng. Exp. Sta. Bull. 447, 48 pp., 1958.

Effects of small amounts of inelastic action were evaluated analytically and experimentally to determine load-carrying capacity and deformational behavior under eccentric tensile or compressive loads on rectangular, tee or angle sections of annealed rail steel, alloy steel, stainless steel and aluminum alloys. Theoretical interaction equations are developed in general terms for members subjected to axial load and bending moment, and theoretical load-moment curves are constructed on assumption that member deflects into segment of circle or cosine curve under eccentric load. In most cases good agreement was found between theory and tests on time-insensitive materials, but for time-sensitive material difference was found unless strain history of members was duplicated in stress-strain specimens.

G. G. Meyerhof, Canada

Structures: Composite

(See also Revs. 2190, 2243, 2268, 2330)

2306. Huang, Y.-S., Column analogy for multi-connected rigid frames, *Scientia Sinica* **8,** 6, 568–579, June 1959.

The present paper gives an extension of the column analogy, making it applicable to the analysis of multicell problems. Each cell is simulated by a single column. The influences of the common member of two neighboring cells are studied and the results are represented by corrections in the load and moments carried by the column. Once the corrected loading for each cell is obtained, further computation is just the same as in the ordinary column analogy.

From author's summary by P. C. Dunne, Brazil

2307. Au, T., and Fok, T. D. Y., Effects of longitudinal forces on portal frame supporting a highway bridge deck, *J. Amer. Concr. Inst.* **30,** 8, 851–865, Feb. 1959.

Longitudinal forces resulting from live load on a highway bridge deck and from bearing friction at supports of bridge girders produce shear, bending, and torsion in the supporting pier. Authors analyze a type of pier often used in highway bridges, namely the portal frame fixed at supports, subject to such forces. Loading is assumed unsymmetrical with respect to the center line of the portal frame. Analysis by moment distribution is extended to include the effects of torsion. The advantages and limitations of the method of analysis are discussed, and the solution for frames with prismatic members is formulated.

From authors' summary

2308. Scheer, J., Application of programmed automatic computers for problems in statics with an example of continuous beam calculation. Parts I and II (in German), *Stahlbau* **27,** 9, 225–229, Sept. 1958; **27,** 10, 275–280, Oct. 1958.

A matrix method, which is a modification of the "reduction method" of S. Falk [*Ing. Arch.* **24,** 3, 216–232, 1956; AMR **9**(1956), Rev. 3917], is presented for the calculation of deflections of beams with intervalwise constant sections. The vector of deflection, slope, moment and shearing force at one end of an interval can be calculated from the corresponding vector at the other end and from a matrix which depends on the properties of the section, interval length and magnitude of the uniformly distributed load within the interval. Discontinuities at boundaries of intervals (concentrated forces or moments, displacements) can be allowed for through "step-vectors." By matrix-algebra the "span-matrix" relating the vector at one support of the span to that at the other support is built up. An extension is presented for multi-span beams, permitting the gradual elimination of the statically indeterminate quantities. The resulting equation obviates the solution of a large number of simultaneous equations. Flow sheets for programming the method on a digital computer are presented. In an example quoted, a 5-span beam with 44 intervals was analyzed; deflections, bending moments, shearing forces and stresses were calculated in 68 sections on an IBM 650 in 7 minutes.

G. Sved, Australia

2309. Chen, L. H., Piping flexibility analysis by stiffness matrix, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 608–612, Dec. 1959.

There exists a large number of methods of analysis of piping flexibility, each method being particularly advantageous in the case of some particular type of structure. Most of these methods have been developed assuming hand computations as the main mathematical tool. The present paper promotes the use of present-day electronic digital computers for analysis of complex systems by means of a methodical matrix formulation. It makes use of Brock's matrices of influence coefficients and matrices of linear transformation [AMR **6**(1953), Rev. 2765 and AMR **8**(1955), Rev. 2701] and is a logical extension of Brock's work. Reviewer believes that an important new element in present paper is the introduction of stiffness matrices, the inverse of matrices of influence coefficients, and the formulation of the problem with the displacements rather than the redundant forces as unknowns. This formulation is particularly suitable when the number of branch lines, loops and anchor points is large but the number of branch points is relatively small. Author points out that the advantages of his method at its present stage of development are quickly nullified when the piping system involves a large number of partial constraints at intermediate points.

Suggested related reference is the matrix treatment of structures by Roussopoulos [AMR **13**(1960), Rev. 249].

D. C. Gazis, USA

Book—2310. Varlet, H., Hydraulics of water power plants, Vol. I and II [Usines de Derivation, Vol. I and II, Captage des eaux, canalisations a écoulement libre; Conduites forcées, tunnels d'amenée en charge, usines souterraines], Paris, Eyrolles, 1958, 341 pp. 4 920 F; 1959, 274 pp. 4 673 F.

These volumes continue the first part of "Usines hydrauliques, Aménagement, utilisation et prix de revient" ("Water power plants, development and costs"). The first volume is dedicated to open-channel derivation, headrace and tailrace canals, dams, spillways, and tunnels without pressure. The second volume presents penstocks, water-hammer problems, surge chambers, and underground power plants. The work is designed for practical application, with only most important theoretical background, is well edited and illustrated.

These books may be of interest for our hydraulic engineers, as a cross section of methods applied in France. They can be read and understood with a slight knowledge of the French language.

S. Kolupaila, USA

2311. Guerreiro, M. Q., Poisson ratio for concrete in Portuguese dams determined from strains measured in situ (in Portuguese), Minis. Obras Publicas, Lab. Engen. Civ., Lisboa Mem. 135, 15 pp., 1958.

After presenting and discussing the assumptions on which the method is based, an expression for calculating Poisson ratio is deduced from them. The influence of the precision of strain measurements on the value of ν is briefly studied and a criterion is deduced for judging the values of ν obtained.

An example of application is presented as well as some results of other applications, which are also discussed.

The conclusion is reached that the set of values obtained for ν is of some interest, that the influence of creep on ν, if any, is very slight and should be contained in the dispersion of the results. In addition, a very important, although subsidiary, conclusion regarding compatibility of strains is obtained from the study.

From author's summary

2312. Kiselev, V. F., Methods of calculating the strengths of longeron and caisson wings (in Russian), *Avtoref. Diss. Dokt. Tekhn. Nauk, Moscow, Aviats. In-ta,* 1957; *Ref. Zh. Mekh.* no. 7, 1958, Rev. 8152.

2313. Thurston, J. W. G., Transverse strength, *Quart. Trans. Instn. Naval Arch.* **100,** 4, 407–417, Oct. 1958.

Machine Elements and Machine Design

(See also Revs. 2241, 2267, 2449)

2314. Johnson, R. C., The dynamic analysis and design of relatively flexible cam mechanisms having more than one degree

of freedom, *ASME Trans.* **81B** (*J. Engng. Industry*), 4, 323–331, Nov. 1959.

Article treats vibrations of a chain of masses and springs. Direction of vibrations follows the line of motion forced by a cam, against which the spring last in chain is leaning.

Number of masses, i.e., degrees of freedom, has to be finite to enable analysis by the numerical method suggested. Shape of the cam is determined as necessitated by the motion required of one of the masses, while displacement and acceleration of the other masses is calculated.

Examples given have two masses in the chain, accurate cam dimensions and motion analysis obtained by desk calculator only. Fast accelerations by the cam are necessary for smooth actuation of the mass opposite it at the end of the chain.

Cam's speed is lower than basic natural frequency of chain; mechanism being rather rigid and not a resonating system.

Calculations are always for one definite speed of cam—other speeds producing different motions of the masses.

Although author bases article on a previous one ["The extension of finite differences to the dynamic analysis and design of relatively flexible cam mechanisms," Fifth Conference of Mechanisms, Purdue University, October 1958; to be published in the Transactions of the Conference], redevelopment of formulas is possible without referring to it.

J. Boas Popper, Israel

2315. Bock, A., Influence of forces upon the operational characteristics of gears (in German), *Maschinen bautechnik* **8,** 4, 209–216, Apr. 1959.

2316. Cheaney, E. S., Paullus, C. L., and Raridan, W. C., The design and application of belts, chains, and gears, ASME Design Engng. Conf., Philadelphia, Pa., May 1959. Pap. 59–MD–5, 11 pp.

2317. Poocza, A., A possibility to increase the reduction ratio with epicyclic gearings powered by direct-mounted driving motor (in German), *ZVDI* **101,** 7, 274–276, Mar. 1959.

The gear ratio of epicyclic trains powered by electric motors can be increased through the application of the reversing principle. Its outstanding characteristic is that a rotary motion is imparted to the motor frame, in the opposite direction to the rotation of the rotor. An investigation into the kinematic and dynamic relations of gearing designed on this principle, taking efficiency into account, showed that the effectiveness of the proposed type of gearing was between the worm drive and conventional toothed gearing.

From author's summary

2318. Lidin, L. G., On helical-spring suspension, Trans. Chalmers Univ. Technol. no. 210, 75 pp., 1959.

Paper treats theoretical and experimental determination of natural frequencies of mass-spring systems of the type used for machinery suspensions and other vibration isolation systems. Tension and compression springs are considered and all possible coupled and uncoupled modes are studied. Agreement between theory and experiment is good.

Reviewer feels that this paper does not represent an original contribution but provides a useful summary and compilation of data for suspension system designers.

G. A. Nothmann, USA

2319. Modrey, J., Analysis of complex kinematic chains with influence coefficients, *ASME Trans.* **81E** (*J. Appl. Mech.*), 2, 184–188, June 1959.

Complex kinematic chains involving a large number of links (eight or more) are solved by means of influence coefficients. First-order, second-order, and higher-order complexity systems are defined. This article is concerned with higher-order complexity problems. Influence coefficients are obtained by sequentially setting all variables but one to zero and relaxing appropriate constraints to maintain mobility. Simultaneous solution of equations is eliminated. Influence coefficients of simplified mechanisms can be used to obtain velocities and accelerations of the related complex mechanism. One example is presented.

W. B. Stiles, USA

2320. Thiel, R., Investigations into the modulus of elasticity and slippage conditions of vee belts (in German), *ZVDI* **101,** 8, 309–318, Mar. 1959.

In practice the torques occurring in vee belt drives are mostly fluctuating and with larger amplitudes than are necessary for the transmission of the effective power. Alternating or considerably fluctuating torques for the transmission of the real and reactive powers occur especially in drives for the acceleration and retarding of masses with inadequate storage for the potential energy. But, in general, excessive torques can result through vibration phenomena in vee belt transmissions with alternating or constant torque loading, which frequently result in reducing the life of the vee belting. Measurements taken of vee belts in operation showed that when quickly changing torques were transmitted marked resonance phenomena occurred, the evaluation of which for three different types of vee belting produced coefficient data for the dynamic modulus of elasticity frequencies. With the aid of these data vibration can be approximately calculated, to prevent from the outset the coincidence of working and resonance frequencies and, consequently, the creation of unfavourable operating conditions. The effect of the varying torque curve on vee belt life is to be established at a later date through long-duration tests. The electrical measuring method applied when investigating the phenomena of motion on the vee belt transmission permits a good insight to be obtained of the slippage conditions on vee belts. Aided by such systematic measurements it might also be possible to obtain further theoretical clarification of vee belt phenomena.

From author's summary

2321. Ota, T., Hamada, M., Shindo, A., and Maezawa, T., Researches on the strength of shell disc, *Bull. JSME* **2,** 6, 286–299, May 1959.

The wheel disk dealt with consists of two flat spherical shells which connect boss and rim. By means of usual membrane theory and bending theory, the stress states are determined which arise under the following five actions: force fit of axle, shrinkage fit of tire, central thrust, axle load, moment of side thrust. The first two cause initial stress states. The latter two cause nonsymmetrical stress states, and meanwhile, the boss and rim are assumed to be rigid, for simplicity. This assumption entails larger errors than those due to approximations made in bending theory. A numerical example and comparisons with the experimental results and other simple calculations are shown. The initial stresses are large and the type of spherical shell is especially disadvantageous, as it causes very large bending stress. For axle load, the calculation assuming the rigid rim and tire does not agree with the experimental value which is concentrated in the direction of loading. But the stresses due to the axle load will be small even if the load is unequally divided between disks. On the contrary, the assumption is reasonable for the side thrust and the calculated values agree with the experimental result. As the stresses due to axle load and side thrust are superimposed in the inside disk, the desirable design is that in which the axle is supported mostly by other disk.

From authors' summary by J. Barta, Hungary

2322. Parish, G. J., Apparent slip between metal and rubber-covered pressure rollers, *Brit. J. Appl. Phys.* **9,** 11, 428–433, Nov. 1958.

Author's experiments show that the effective rolling radius of the rubber-covered roller is greater than its free radius regardless of whether it is the driver or the driven roller. However, if it is driven, the apparent increase in radius (or the apparent slip) is larger than when it is driving. Hence author proposes slip to be made up of two components, one due to the (symmetrical) deformation of the rubber under the pressure of the metal roller, the other due to the shear between drive and driven roller. Thus, the second cause changes sign when driver and driven roller are reversed, the first does not.

Author separates the two effects from experiments with a laboratory mill. He also computes the effect of the first cause, static deformation, which is independent of roller velocity. He uses plane strain solution assuming small strains and, despite the questionable nature of these assumptions, his results check the experimental results quite well. E. G. Chilton, USA

2323. Berry, P. E., Research on oscillating conveyors, *J. Agric. Engng. Res.* **3,** 3, 249–259, 1958.

Oscillating conveyors are used extensively in agriculture in various forms and the absence of any published theory of their mode of operation has retarded design and development. Some initial aspects of a program of theoretical and practical research are briefly described together with some of the points which still have to be investigated. From author's summary

2324. Davletshin, Kh. G., Theory of the three-dimensional motion of a spherical valve of a piston pump (in Russian), *Trudi Mosk. Neft. In-ta* no. 20, 260–287, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 476.

The motion described in the title is investigated. Basic equations for the motion of the valve are derived. It is shown that for a spherical valve there can be no hard and fast relations between the angle of lag, the speed of setting and the performance of the pump. It is also shown that the motion of the spherical valve is accompanied by impact on the seating and the casing even in the most moderate conditions for the deep-seated pump.

V. L. Ivanov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Fastening and Joining Methods

(See Rev. 2268)

Rheology

(See also Rev. 2658)

Book—2325. Mill, C. C., edited by, Rheology of disperse systems (Proceedings of a conference organized by the British Society of Rheology, University College of Swansea, September 1957), New York, Pergamon Press, 1959, vii + 223 pp. $9.50.

Book begins with a clear theoretical paper on complicated rheological properties by J. G. Oldroyd. It is shown that the principle of material objectivity implies that in the treatment of even the simplest elastic-viscous dispersions nonlinear equations cannot be avoided once all restrictions on the magnitude of the rates of strain are removed. As a consequence these materials must exhibit Weissenberg effects, in a positive or negative sense, as well as variable viscosity and cross-viscosity effects, with different types of normal stress-differences occurring in different cases. Only infinitely dilute emulsions and suspensions are at present amenable to theoretical analysis. The remainder of the paper is devoted to semi-empirical formulas, experimental techniques and results. S. G. Mason and W. Bartok, "The behavior of suspended particles in laminar shear," consider distortion and interaction of particles theoretically and experimentally. R. L. Whitmore, "The viscous flow of disperse suspensions in tubes," explains decreasing viscosity with decreasing tube diameter by slight fall of particle concentration due to mechanical interaction between wall and particles. G. F. Eveson, "The viscosity of stable suspensions of spheres at low rates of shear," investigates the influence of the size distribution of the solid phase. N. Casson, "A flow equation for pigment-oil suspensions of the printing ink type," develops a semi-empirical formula from the consideration that the particles in a flocculated suspension form chain-like groups, the dimensions of which control the viscosity of the suspension. E. Bantoft, "Some measurements on pigment-plasticizer dispersions," notes that a few pastes appear to show a negative Weissenberg effect. A. Jobling and J. E. Roberts, "Some observations on dilatancy and thixotrophy," discuss the application of Weissenberg's deformable membrane technique. W. A. Dukes, "Rheological measurements on lutings," makes a critical comparison of different ways of measuring both the yield value and apparent viscosity. E. H. Steiner, "The rheology of molten chocolate," describes measurements with several different types of rotational instruments. R. S. Lenk, "Starch-clay coating mixes; the inter-relationship of amylose content, total solids content and rheological properties," finds that the viscosity characteristics can be largely controlled by varying the total solids content. T. C. Daniels, "Density separation in gaseous fluidized beds," attempts to use the falling-sphere method of measuring viscosity.

To each paper a record of the discussion is added. Book contains valuable information on rheological properties of various materials, and gives, in reviewer's opinion, a clear illustration of the gap between theory and experiment.

J. F. Besseling, Holland

2326. Lamb, C. A., Verification problems in paper making, Proceedings of the Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16–18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 143–161.

The process of paper-making is well established, but largely on empirical ideas. Recent papers by Taylor and Lewis attempt to analyze the motion of the slurry on the bed. In present paper some of the premises made by Taylor and Lewis are questioned. Author makes model experiments on the process of "spouting" whereby paper is weakened at spots where the jets of water return to the bed.

"Spouting is a splash resulting from nonuniform flow impinging on the wire. Additional work is required to verify whether internal resistance, surface tension and gravity are negligible at higher machine speeds." E. G. Richardson, England

2327. Rebinder, P. A., and Ivanova-Chumakova, L. B., Structural-mechanical (viscous-elastic) properties of solutions of polymers and methods for their measurement (in Russian), Advances in the chemistry and technology of polymers (Uspekhi Khimii i Tekhnologii Polimerov) Moscow, Goskhimizdat **2,** 146–170, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 1068.

For the investigation of the rheological properties of solutions of polymers in an almost homogeneous field of stresses–deformations, rotating viscosimeters were used of the type exemplified by Shvedov and Gudiv's apparatus with torsional dynamometers and narrow clearances between the movable and immovable parts of the working instrument, and also apparatus based on the shear of the samples of the material having the form of parallelopipeds between two fluted plates. For the description of the structural-mechanical properties of the solutions of the polymers a system of rheological characteristics was used. The authors differentiate between two types of stress relaxation: the real, conditioned by

the "secular" yield of the materials with the largest limit of viscosity, and the elastic, conditioned by the redistribution of stresses in the course of time between the "momentarily elastic" and the elastic elements. An equation is proposed for the elastic relaxation of solutions of high polymers, having the form of

$$P - P_L = (P_0 - P_L) \exp\left(-\frac{\tau}{\theta^*}\right), \quad P_L = P_0 \frac{E_2}{E_1 + E_2}$$

where P_0 and P are the initial stress and the stress to the moment of time τ, θ^* is the period of elastic relaxation, E_1 and E_2 are the conditionally momentary and elastic moduli.

N. I. Malinin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Hydraulics

(See also Revs. 2310, 2347, 2354, 2518, 2579, 2639, 2640, 2641, 2656, 2659)

2328. Ball, J. W., Hydraulic characteristics of gate slots, *Proc. Amer. Soc. Civ. Engrs.* **85,** HY 10 (*J. Hyar. Div.*), 81–114, Oct. 1959.

Paper describes a comprehensive and continuing investigation by the U. S. Bureau of Reclamation Hydraulic Laboratory of slots for water gates of the roller or slider type. Turbulent surging within the slots and cavitation downstream of the slots can lead to severe damage, troubles met as early as 1905 but now more serious with the use of higher heads. Pressure-distribution measurements on model slots, first with water and later with air flow, enabled a variety of slot shapes to be assessed for proneness to cavitation and led to the development of cavitation-free designs for heads as high as 200 feet. Most of the models were of the slot only, without the gate leaf, and experiments showed that this system was applicable to a wide range of gate openings. The model experiments were related to field experience, where the importance of smooth continuous flow surfaces was evident.

The pressure-distribution results are expressed in terms of the ratio of local static pressure change to velocity head, not in terms of cavitation number, and full information on experimental conditions is not given. The actual head producing cavitation in a field installation was always much lower than predicted by the vapor-pressure criterion applied to the model results. Model results with water and with air were in good agreement. Author concedes that data presented do not pinpoint cavitation characteristics of various slot designs, but makes the reasonable claim that useful comparative information is made available.

J. A. Cole, Australia

2329. Kvardakov, A. F., Coriolis coefficient in a flow of water passing through some hydro-installations (in Russian), *Trudi Sibirsk. Avtomob.-dor. In-ta* no. 6, 135–149, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 399.

During analysis of a number of problems on engineering hydraulics the author points out the influence of the Coriolis coefficient on the final results of a calculation. Examples are given of the influence of the Coriolis coefficient on the mutual and compressed depths in a jump, on the magnitude of the critical depth, on the criterion of similarity of the flows of liquid. Data on the Coriolis coefficient cited in the literature are put forward and experimental data are also furnished, the outcome of the author's specially carried out experiments in a trough, determining the numerical values of the Coriolis coefficient.

A. M. Latyshenkov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2330. Paal, L. L., The dying-out of energy in the lower water of hydroconstruction in conditions of a bottom regime of linking (in Russian), *Trudi Tallinsk. Politekhn. In-ta* **A** no. 116, 32 pp. + illus., 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 453.

The problem is examined on the dying-out of the velocity pulsations on the "after jump" portion of the flow in conditions of a base regime of linkage of the lower waters when energy dampers are absent. The author fixes as his target the study of the magnitude of the tangential stresses on the bottom of the flow in conditions of an intensive pulsation of velocities. For this purpose he assembled apparatus consisting of a transmitter in the form of a horizontal slab joined to a flexible vertical rod. The declination of the slab from the horizontal plane with changes of the magnitude of the tangential stress was recorded by means of the photoresistance from the layer of a semiconductor enclosed between two current-conducting electrodes. With the aid of this apparatus the author obtained the value of the magnitude

$$\varphi = \frac{\tau h_{cr}}{q v_2^2 b_2}$$

where v_2 and b_2 are the velocity and depth on the apron, h_{cr} is the critical depth. The curves $\varphi = f(s/h_{cr})$ give the regular decrease in relation to the withdrawal from the constricted section of the flow. The values of the coefficient of increase of the eroding capacity of the flow on the section of linked "waters" are furnished and the calculated relation for the size of the stones used in the strengthening of the river bed below the fall. The experiments carried out give proof of the large magnitude of the tangential stresses at the bottom of the flow at the site of the jump and provide new material regarding the oblique characteristic of the damping of the pulsations within the apron limits. The possibility of going over from tangential stresses to conditions of stability of the particles is not sufficiently clarified in view of insufficient consideration of the parts played by the lifting power and pressure pulsations.

I. I. Levi

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2331. Bolshakova, V. V., Organization of field investigations on the effects of wave action on the hydrotechnical constructions of large hydro assemblies (in Russian), *Sb. Trudi Mosk. Inzh.-Stroit. In-ta* no. 20, 169–181, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 353.

The expediency is noted of a wide arrangement for investigations in situ of hydrotechnical constructions subjected to wave action. Among the basic objects of the investigations would be the reinforcement of earthen slopes of the constructions and of the banks, of the spill-way dams and weirs. Making use of the materials at the disposal of the faculty of the Management of Water and Seaports of the Moscow Engineering-Constructional Institute, recalculations are made of the problems under investigation, equipment is recommended and some schemes are put forward for the location of the apparatus on the constructions being examined.

A. S. Ofitserov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2332. Campbell, F. B., and Pickett, E. B., The value of prototype tests to hydraulic design, Proceedings, Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16–18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 273–300.

Paper deals mostly with prototype tests made since 1951 by the Waterways Experiment Station of the Corps of Engineers, especially on overflow and chute spillways, sluice and conduit entrances, exit portals, and stilling basins. Also discussed are discharge coefficients of gates and valves, the forces on gates and their vibrations, cavitation, and air demand. Along with the

prototype data, some data on corresponding models are given. Difficulties of making prototype measurements for pressures, velocities, and discharges are discussed, and new methods proposed.

Discussion by several present at the Conference is included. Paper contains much information helpful to the designer. Tests on the 20-ft diameter outlet conduit of Denison Dam 11 years after construction, at a Reynolds number of 120 million, gave f approximately 0.0065, compared to 0.0058 by Prandtl's smooth-pipe formula, which is remarkable since the data on which the latter was based went to only 3,230,000.

Apparatus for measuring the absolute roughness of large conduits is described, but evidently it measured only the height of the roughnesses, and not their longitudinal spacing or shape.

R. W. Powell, USA

2333. Hudson, R. Y., Laboratory investigation of rubble-mound breakwaters, *Proc. Amer. Soc. Civ. Engrs.* **85,** WW 3 (*J. Water. Harbors Div.*), 93–121, Sept. 1959.

Results of laboratory tests of the effects of waves on small-scale rubble-mound breakwater sections are reported. Limit of stability of protective cover layers composed of simulated quarry-stone and tetrapod-shaped armor units is determined as a function of wave dimensions, slope of exposed breakwater face, weight and specific weight of armor units. Based on a rational analysis of the forces exerted on armor units when waves impinge on rubble-mound breakwaters, a formula is derived for the weight of armor units required to insure their stability. The new formula is dimensionally homogeneous and contains only one experimental coefficient. Test data obtained to date indicate that the experimental coefficient varies primarily with the shape of armor unit and the amount of damage to the cover layer. For the quarry-stone-type armor unit, and for the no-damage and no-overtopping criteria, the experimental coefficient is constant.

Wave run-up data were also obtained for the breakwater section and wave conditions used. Wave run-up is found to decrease when values of the steepness of the waves and the breakwater slope are increased. The thickness and porosity of cover layers were also determined as a function of shape, weight, and specific weight of the armor units.

G. Noseda, Italy

2334. Hunt, I. A., Jr., Design of seawalls and breakwaters, *Proc. Amer. Soc. Civ. Engrs.* **85,** WW 3 (*J. Water. Harbors Div.*), 123–152, Sept. 1959.

Author discusses the hydraulic rather than the structural aspects of the problem of breakwater and seawall design. A thorough survey of available literature is made and some comparisons with experimental results obtained by the author are presented. The various ways in which the wave energy is dissipated are discussed and a summary of the effects of the slope of the structure and wave characteristics on breaking of the waves is given. The Iribarren formula is found applicable for continuous slopes. The major part of the paper is concerned with the magnitude of the "up-rush," or the effective rise of water on the breakwater. This, in reviewer's opinion, is not necessarily a measure of energy dissipation, as appears to be assumed by the author, but nevertheless it is an important factor in design. Effect of such factors as discontinuous slopes, berms, surface roughness and porosity on the magnitude of the up-rush is presented in form of useful empirical coefficients.

It is a pity that the form in which the formulas are presented is dimensional (without an explicit statement of the units used). No major complication would ensue from a more general statement.

C. C. Zienkiewicz, USA

2335. Johnston, A. K., Observations on floating breakwaters for reflection of shallow water waves, Parts I and II (English and French versions), *Houille Blanche* **13,** 5, 540–550, Oct. 1958; **13,** 6, 619–638, Nov. 1958.

Steep waves coming into shore erode beaches; low calmer waves build beaches. Partial reflection of incoming steep waves, by a floating barrier, may convert potentially destructive waves to constructive waves. Floating barriers, in the past, relied on inertia for wave reflection, but such systems were "effective" (50% of wave energy reflected) in waves with periods up to 6 seconds. By making barrier an open-ended container, author employs principle of resonance (as well as inertia) in order to reflect longer waves.

Author treats inertial and resonant reflection separately and combines results taking heaving motion of barrier into account. Inertial case supposes barrier as wave generator. Solution of second-order differential equation results in wave height ratios given as "transmission and reflection coefficients." The resonator-reflection part is treated by considering equation of motion of water particles inside chamber excited by a pure sinusoidal external force. Simplified assumptions on linearity of the system result in poor estimates of reflection in the resonant frequency band. Experiments are needed to assign quantitative values in this range.

Second part of paper discusses inertia-resonance breakwater design. Horizontal resonator is more promising than vertical because it is easily tuned to reflect any frequency and less subject to heave.

Author finds combination of inertia and resonance effective in waves with periods up to 10 seconds. This system will likely succeed inshore, but not in open ocean, where extension of breakwater to bottom is not practical.

W. Marks, USA

2336. Manohar, M., Part full and transitional flow through culverts (in English), *J. Sci. Engng. Res., India* **2,** 2, 175–194, July 1958.

The part full and transitional flow through pipe culverts with sharp-edged and rounded inlets and free outlets is considered. An unstable flow condition is described which can occur when the upstream level is slightly above a rounded inlet and air pockets proceed along the roof of the culvert. In this condition the discharge can increase several fold for a slight rise in water level. Above a certain discharge, depending on the culvert slope, the bubbles disappear and the culvert behaves as a drowned orifice.

G. H. Lean, England

2337. Asaturin, A. Sh., Edigarov, S. G., and Chernikin, V. I., Hydrotransport of viscous petroleum products in rectangular open channels (in Russian), *Trudi Mosk. Neft. In-ta* no. 20, 314–321, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 486.

An investigation is carried out on the single-dimensional stationary flow of a petroleum stream, under which there is a water stream, running in an open channel of rectangular section with immovable walls, under the influence of the forces of gravity. Assuming that Reynolds number is small and disregarding the inertia terms in the Navier-Stokes equations, authors derive linear differential equations for the velocities of the water and the petroleum. The solution is sought by means of resolution into a Fourier series, the boundary conditions being assigned. In this procedure use is made of the resolution into a Fourier series of the constants, depending on the forces of gravity and on the pressure gradient, which is only justifiable in the open portion by the width of the channel. Formulas are given for the determination of the inputs of water and petroleum and an example is given of an approximate calculation in which the drop in pressure is not taken into account. The authors note that the series obtained by them merge rapidly; proof of this is not forthcoming.

D. E. Dolidze

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2338. Lindgren, E. R., Liquid flow in tubes, Part 1, The transition process under highly disturbed entrance flow conditions (in English), *Arkiv för Fysik* **15,** 2, 97–119, 1959.

Previously reported observations on the transition process in stream bi-refringent tube flow have been repeated in part. New photographic records are presented in order to improve the illustrative material of previous reports [Lindgren 1954; 1957] with respect to the characteristics of the transition process.

Some peculiar features of the stream bi-refringent effects of White Hector bentonite suspensions in tube flow have been discovered and are briefly discussed.

An explanatory discussion shows that the turbulent spots as observed in Blasius flow and the turbulent flashes as observed in tube flow do represent two stages of development of one and the same transition process. They should not be interpreted as representing corresponding manifestations of the transition process appearing in different forms in the two types of flow.

Explanation is also given to the processes of splitting of turbulent flashes within the transition region and to the "continuous" elongation of turbulent flashes (streaks) for higher Reynolds numbers previously observed and reported.

The significance of the fact that disturbances emanating from the tube inlet have a considerably longer time of decay than eddies generated by turbulent flash bodies is discussed and appears to have a bearing on the vortex strength of the turbulent flash bodies.

A recent determination of the intermittency factor as defined for the transition process in tube flow is examined and some necessary adjustments are proposed.

Finally, an examination of the characteristic features of the turbulent flashes confirms that the turbulent eddies are produced within wall-near layers from where they diffuse into central parts of the flow where dissipation takes place. There are some characteristic mass transfer and velocity distribution patterns which appear to play an important role in the maintenance processes of the turbulent flashes. From author's summary

2339. Lindgren, E. R., Liquid flow in tubes, Part 2, The transition process under less disturbed inlet flow conditions (in English), *Arkiv för Fysik* **15,** 6, 503–519, 1959.

Previous findings [see preceding review] are confirmed, according to which transition is caused by primary inlet disturbances of finite strength which cause the initiation of turbulent spots before they fade away and according to which the spots during their downstream travel develop into turbulent slugs. It also is confirmed that the fully developed turbulent slug should be regarded as being composed of a turbulent spot (or spots) travelling along the boundaries and of a central core of eddies with decay maintained by a process of continuous diffusion of eddies from the spot into the core [Lindgren 1957, p. 59; 1959, p. 97].

The "splitting" of turbulent slugs as well as the elongation of turbulent streaks, which phenomena have been reported previously [Lindgren, 1957, pp. 89–91, 110–111, 121–122, 147–148], are found to be due to the core eddies being brought forward of their generating spots. Some of these always decaying eddies may, before they fade away, initiate the formation of a new spot ahead of the original one. The same process may then repeat itself with the new spots with a probability determined by the flow conditions.

The turbulent streaks and possibly also the self-preserving turbulent flow in general appear to be inhomogeneously maintained by discrete turbulent spots. From author's summary

2340. Lindgren, E. R., Liquid flow in tubes, Part III, Characteristic data of the transition process (in English), *Arkiv för Fysik* **16,** 2, 101–112, 1959.

Qualitative studies on the transition process in tube flow of liquids reported in previous papers of this series [see two preceding reviews] have been extended to cover also quantitative relationships of this phenomenon for flow of White Hector bentonite sols of various concentrations.

Experimental evidence is presented which indicates that the transition process depends on some physical—say structural—properties of the liquids which are not accounted for by the coefficient of viscosity and the density. The findings actually demonstrate that the Reynolds law of similarity does not entirely apply to the flows investigated. These findings are supported also by studies of a new transition quantity, the *maximum relative spot velocity* (= maximum relative velocity of the rear of the turbulent slugs as defined previously [Lindgren, 1957, pp. 89–98, 147–148]), the determination of which is independent of the viscosity of the liquids. From author's summary

2341. Gusak, I. V., On the hydraulic resistance of tubes of small diameter (in Russian), *Trudî Kishinevsk. S.-kh. In-ta* **15,** 15–25, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 412.

The investigation on the hydraulic resistance of tubes of small diameter (less than 15 mm) took place in laboratory conditions with tubes of red copper with internal diameters of 3.76 and 5.5 mm and with lengths for the working portions of approximately 1.5 m. The consumption of water was measured by a volumetric method while the pressure loss was gaged by means of a piezometer. Reynolds number varied from 380 to 16,200. The experiments established that the formulas derived for the computation of loss of pressure in tubes of large diameter can not be used for such loss in tubes of small diameter, as they give too low values. Based on experimental work done formulas were obtained which could be recommended for the hydraulic calculations of tubes of small diameter. The experimental results are illustrated by means of graphs. V. I. Gotovtsev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2342. Ball, J. W., Model and prototype stilling basins, Proceedings of the Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16–18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 183–213.

Paper describes stilling basins in which energy dissipation was improved on the basis of model tests. Stilling basins were constructed on the basis of model tests but still show deficiencies—for instance, cavitation—in full-scale operation. Author notes example of reducing cavitation risks by injecting compressed air at critical points. Further, full-scale stilling basins constructed on the basis of model tests proved to be so cheap and effective that construction principle was extended to fit in with wide range in head and discharge, for instance hollow-jet valve stilling basin [see U. S. Bur. Recl. Hyd. Lab. Rep., HYD-446, 1958].

H. T. Kristensen, Sweden

2343. Polikovskii, M. V., Calculation of the delivery and cavitation characteristics of liquid ejector pumps (in Russian), *Avtoref. Diss. Kand. Tekhn. Nauk, Mosk. Energ. In-ta, Moscou,* 1957; *Ref. Zh. Mekh.* no. 7, 1958, Rev. 7658.

Incompressible Flow

(See also Revs. 2398, 2403, 2406, 2421, 2432, 2439, 2442, 2444, 2464, 2474, 2476, 2624, 2644, 2655)

2344. Woo, T. C., The motion of a submerged body moving vertically towards a free surface, Brown Univ., Div. Appl. Math. TR 28, 27 pp., May 1959.

By means of well-chosen combinations of known classical treatments for inviscid and incompressible fluids, author attempts to solve the problem of the forces on a sphere or a cylinder and the form of the free surface.

The applied methods are: (1) image method, i.e. free surface replaced by a fluid above it with a descending image sphere; (2) as (1) but velocity potential interpreted as time integral of pressures, the sphere rising from infinite depth; (3) application of Lagrange coordinates for a cylinder.

(1) gives forces on the sphere; (2) results in expressions for pressures, potential field and surface elevation in the form of integrals; (3) resulted in a general formulation.

Reviewer's opinion is that positive image methods cannot be applied to free-surface problems; only negative images may fulfil the constant-pressure condition.

H. J. Schoemaker, Holland

2345. Schaefer, J. W., and Eskinazi, S., An analysis of the vortex street generated in a viscous fluid, *J. Fluid Mech.* **6,** 2, 241–260, Aug. 1959.

An analytic solution for the velocity field of a vortex street and a method for the determination of the true transverse spacing of vortices are presented. Hot-wire techniques were used to obtain experimental geometry and velocity data to establish the validity of the analytic solution.

W. L. Sibbitt, USA

2346. Newman, B. G., Flow in a viscous trailing vortex, *Aero. Quart.* **10,** 2, 149–162, May 1959.

Linearized theory of a laminar viscous trailing vortex. Axial velocity deficit is not connected with the rotational motion. It has to be estimated from the profile drag by supposing that the wake is eventually absorbed completely by the vortices. An attempt is made to extend the theory to turbulent flow.

L. J. F. Broer, Holland

2347. Strscheletzky, M., Forms of equilibrium of rotationally symmetrical flows with constant whirl in straight hollow cylinders (in German), *Voith Forschung Konstruckt.* no. 5, 1.1–1.19, 1959.

Author considers flow of an incompressible inviscid fluid of constant whirl and constant energy content in straight hollow cylinders. He assumes a cylindrical "dead-water" core of constant vorticity and zero axial velocity, the vorticity being determined by assumption of continuous circumferential velocity at core boundary.

According to author's theory of "hydrodynamic equilibrium" [AMR **10** (1957), Rev. 4109] the flow configuration occurs that has minimum kinetic energy per unit volume, and this criterion determines relation between ratio of core-radius to cylinder radius, r_i/R, and the parameter $Q/(\Gamma R)$, where Q is volume flux and Γ the (constant) whirl.

He then considers axially limited whirling flow, that is, flow that has whirl introduced at one station (by suitable guide vanes, for example) and removed at a subsequent station. He assumes that the changes are discontinuous and that stations are so close together that variations in axial coordinate need not be considered in whirling region. Similar considerations as before give relation between r_i/R and $Q/(\Gamma R)$ for zero axial spacing, and predict increases in core diameters of order of 20% over first case, infinite axial spacing.

Comparison with experiment seems good when measurements for zero spacing case are made immediately in front of whirl-destroying device, and, for infinite spacing, are made greater than three diameters upstream of device. Author claims that increase in core diameter in front of such devices is of practical importance in selecting hub-diameter of turbomachines.

H. C. Levey, Australia

2348. Brewster, D. B., Grosberg, P., and Nissan, A. H., The stability of viscous flow between horizontal concentric cylinders, *Proc. Roy. Soc. Lond.* (*A*) **251,** 1264, 76–91, May 1959.

The critical conditions for the formation of Taylor vortices between horizontal concentric cylinders are considered in detail:

(1) Where the flow is unidirectional round the annular space and is caused entirely by the rotation of the inner cylinder.

(2) Where the flow is caused entirely by pumping round the annular space.

(3) Where a liquid is caused to reverse its flow at a free surface, the flow being entirely caused by the rotation of the inner cylinder.

The last case is analyzed by the method of small disturbances and the conditions under which Taylor vortices will form are found. Results for the first two cases are already available in the literature. From examination of the three criteria a dimensionless number is proposed to correlate the critical values of the various parameters at the onset of these Taylor vortices. The proposed number has the advantage that it is insensitive to the velocity distribution in the annulus. It is subsequently used to predict the critical conditions for the onset of Taylor vortices under conditions that have not been analyzed, i.e. where flow is due to pumping and rotation of the inner cylinder. The criterion is found to predict successfully the results of various experiments carried out. In addition, experimental verification of the theoretical work of Dean (1928) and of the additional analysis carried out in this paper is also given.

From authors' summary by H. A. Einstein, USA

2349. Suponitskii, A. M., On potential flow of an incompressible liquid through a circular array of plates (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 10, 95–98, Oct. 1957.

Consider grid of n flat plates of chord $2l$ with midpoints $z_k = x_k + iy_k = a \exp 2\pi ik/n$, $k = 0, 1, \ldots, n-1$. Suppose kth plate intersects ray Oz_k at angle θ independent of k. Plane flow about grid is produced by complex source-vortex at origin O and vortex distribution of strength $\Gamma(s)$ on each plate, s being distance from midpoint of plate. Boundary condition of tangency of flow on plates yields singular integral equation for $\Gamma(s)$, supplemented by Joukowskj condition of finite velocity at plates' trailing edges. Set $\Gamma(s) = \sum_0^\infty \gamma_j(s)\, \varepsilon^j$, where $\varepsilon = l/a$ is assumed small.

Substitute in integral equation and equate to zero coefficients of ε^j to obtain infinite set of singular integral equations for $\gamma_j(s)$, general solutions of which are known. Author determines explicitly γ_j for $j = 0, \ldots, 3$. For $\theta = 0$ exact solution can be found independently. Author compares total circulation around one plate for $\theta = 0$, $\varepsilon = 0.1$, and various n, calculated by his approximate third-order method and values found from exact solution. Errors range from 0% for $n = 2$ to 10.1% for $n = 12$.

J. H. Giese, USA

2350. Pond, H. L., The moment acting on a Rankine ovoid moving under a free surface, *J. Ship Res.* **2,** 4, 1–9, Mar. 1959.

The moment is calculated using Lagally's theorem. Assuming as a first approximation that the ovoid is generated by the same source-sink system as in an unbounded fluid, the calculated moment values do not agree with experimental results. The main part of this discrepancy may be explained by the distortion of the body by the presence of the free surface. A second approximation is introduced by assuming an additional dipole distribution following a method due to von Karman by which the distorting cross flow is compensated. Highly satisfactory results for the moment are obtained. Graphs are included.

G. P. Weinblum, Germany

2351. Kestin, J., and Newell, G. F., Theory of oscillation type viscometers: The oscillating cup. Part I, *ZAMP* **8,** 6, 433–449, Nov. 1957.

The torsional motion of a mass suspended on a wire is an exponentially decaying harmonic if the frictional resistance is proportional to the velocity, If the mass is a symmetrical cup to which a nonviscous liquid is added the motion is unchanged. But if the liquid is viscous the deviation of the motion provides a clue

to the viscosity. Paper presents a condensed, but orderly, analysis of the relationship and shows that the motion is a damped harmonic oscillation about a reference position which drifts asymptotically toward the equilibrium position. The circumstances under which the drifting is negligible, so that the apparent frequency and decrement of the oscillation may be used to compute the viscosity, is discussed.

Authors' statement that the solution is exact may be misunderstood. The evaluation of the inverse Laplace transform of the motion is exact, but this reviewer believes that the defense of the premise on which the hydrodynamic model rests is unacceptable. Extrapolation toward zero amplitude achieves nothing unless it is first established that the effects of the normal and radial velocities are second-order. In this connection it should be noted that, for the oscillating disk, the tangential velocities pass through zero while the normal and radial components remain finite.

W. J. Moreland, USA

2352. Beckwith, D. A., and Newell, G. F., Theory of oscillation type viscometers: The oscillating cup. Part II, *ZAMP* **8,** 6, 450–465, Nov. 1957.

Paper examines the conditions under which the cup viscosimeter may be expected to give minimum error in the computed viscosity. Criteria are established for the identification of the small, intermediate and large types which should be of value in the selection, design and operation of the viscosimeter.

Some of the errors inherent in the free-vibration viscosimeter are overcome in a new type steady-state null-reading viscosimeter under study at the Wright Air Development Division. This instrument will disclose the presence of nonlinear effects by the excursion of the index from the null position. W. J. Moreland, USA

2353. Debler, W. R., Stratified flow into a line sink, *Proc. Amer. Soc. Civ. Engrs.* **85,** EM 3 (*J. Engng. Mech. Div.*), 51–65, July 1959.

The discharge of a stratified fluid (with a stable linear density variation at infinity) through a horizontal slot at the end of a channel has been investigated experimentally. The experiments show that when the densimetric Froude number is less than 0.28 the flow pattern is divided into two horizontal regions: an upper, essentially stagnant, region and a lower region in which the entire discharge is concentrated. The specific results obtained are useful for the solution of many engineering problems involving stratified flows.

From author's summary by J. S. McNown, USA

2354. Zarembo, L. K., and Shklovskaya-Kordi, V. V., A method of visualizing acoustic flow on the boundary of two immiscible liquids (in Russian), *Akust. Zh.* **3,** 4, 373–374, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 132.

This communication concerns the relatively simple method of observing the line of current on the boundaries of two immiscible liquids (glycerine and vaseline oil) during acoustic flow produced by ultra sound (in the experiment a frequency of 1.5 m Hz was used and an ultra sound intensivity of several watt/cm^2). A colored drop of water falling into a layer of vaseline oil, which was on the top (the density of vaseline oil at 20° = 0.9 g/cm^3), penetrates to the layer of glycerine with a higher density than the water. Due to surface tension this drop assumes the shape of a circular film which, under the action of acoustic flow caused by ultra sound, begins to change its position. The movement of the film leads to part of the coloring matter falling on the line of current and thus demarcating this line. A photograph is given of the progressive development of the motion over a period of time.

V. A. Krasilnikov

Courtesy Referativnyi Zhurnal, USSR Translation, courtesy Ministry of Supply, England

2355. Rosenblat, S., Torsional oscillations of a plane in a viscous fluid, *J. Fluid Mech.* **6,** 2, 206–220, Aug. 1959.

Author expands velocity components in ascending powers of the small amplitude of oscillation, determining the transverse component to the third order. The radial and axial components are found to the second order, and in addition to the oscillatory terms these behave at large distances from the plate as a steady irrotational stagnation flow. That this last result is erroneous is shown to be due to the divergence of the power series outside the boundary layer. An alternative Pohlhausen method is used to demonstrate that the steady component of the radial-axial flow is actually a viscous flow confined to a boundary layer beyond the boundary layer, in which the convective inertia terms, though small, cannot be neglected. J. N. Hunt, England

Compressible Flow (Continuum and Noncontinuum Flow)

(See also Revs. 2297, 2397, 2404, 2410, 2418, 2419, 2420, 2448, 2470, 2472, 2512, 2513, 2515, 2520, 2534, 2538, 2540, 2589, 2616, 2618)

2356. Levy, L. L., Jr., and Yoshikawa, K. K., A numerical method for calculating the wave drag of a configuration from the second derivative of the area distribution of a series of equivalent bodies of revolution, NASA Memo 1-16-59A, 91 pp., Apr. 1959.

The integral form of the wave drag of slender non-lifting configurations is approximated by a summation which is more amenable to evaluation by digital computers. It is shown that if the second derivative of area $S''(x)$, of the equivalent bodies of revolution, is approximated by the sum of its first differences, then the double integrals can be approximated by double sums. Each term in the summation is the triple product of two first differences and a weighting function which is tabulated.

Author suggests (1) that it is advisable to use about 200 equally spaced stations along the longitudinal axis of the configuration, (2) that it is preferable to derive first differences of $S''(x)$ from a distribution of $S'(x)$ rather than of $S''(x)$, and (3) that the total zero-lift wave drag of a system of slender bodies of revolution can be calculated more rapidly and more accurately by adding the drag for each component and the interference drag for all pairs of components.

Appendices contain methods for (1) evaluating interference wave drag, (2) approximating wing thickness distributions, and (3) calculating lift, area, and derivative distributions for sheared wing and tail components.

For bodies of revolution, the present method is alternative to that using second differences of $S(x)$ proposed by Cahn and Olstad in a contemporary report [AMR **12**(1959), Rev. 4575]. Reviewer considers that certain advantages might accrue from amalgamation of results contained in these two reports.

S. Kirkby, England

2357. Caglioti, V., and Furlani, C., Study of a system of differential equations of gas dynamics (in Italian), *Atti Accad. Naz. Lincei, R.C. Cl. Sci. Fis. Mat. Nat.* (8) **24,** 6, 633–642, June 1958.

2358. Sulakh, B. M., Nonlinear conical flow of a gas, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22,** 6, 1109–1120, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author finds Giese's and Cohn's paper on the subject [*Quart. Appl. Math.* **12,** 1955; AMR **8** (1955), Rev. 2775] not clear and convincing enough; he offers another approach which is highly mathematical. Quasi-linear differential equations of the second order are reduced to canonical equations. Developed is a method of second approximation in nonlinear theory of irrotational steady

conical gas flows. Making use of certain properties of analytical functions, he first transforms the differential equation for irrotational nonlinear flow into a system of analytically simpler equations, and then applies to them the method of successive approximations, which are carried out through the introduction of new variables and conformal transformations. Finally, the accuracy of the second approximation is checked for a circular cone. The most interesting result of the paper is the following expression for the pressure coefficient on the cone surface:

$$C_p = -\varepsilon^2 - 2\varepsilon^2 \ln\frac{m\varepsilon}{2} + \frac{2}{m}\varepsilon^3 \ln\frac{m\varepsilon}{2} + 2\left(\frac{1}{3m} - \frac{1}{3} + \frac{m}{4} + \frac{5}{6}\frac{M_0}{m}\right)\varepsilon^3 + m^2\varepsilon^4 \ln\frac{2m\varepsilon}{2} + 2\left(M_0^2 - \frac{1}{m^2} - 1\right)\varepsilon^4 \ln\frac{m\varepsilon}{2} + \left\{\frac{M_0^2}{4} - \frac{2}{3m^2} - \frac{1}{2} - \frac{5}{3}\frac{M_0^2}{m^2} + M_0^2\left[\frac{2\ln 2}{m^2}(2 + (\alpha - 1)M_0^2) + \frac{\pi - 1 - \ln 2}{2}\right]\right\}\varepsilon^4 + O\left(\varepsilon^4 \ln\frac{2m\varepsilon}{2}\right)$$

where M_0 = free-stream Mach number, $m = \sqrt{M_0^2 - 1}$, ε is half angle of the cone.

G. A. Tokaty, USA

2359. Kotlyar, Ya. M., Flow of a viscous gas in the clearance between two co-axial cylinders (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 10, 12–18, Oct. 1957.

Suppose one cylinder is contained inside the other with very small clearances. Gas enters this space through a periodic arrangement of slits in the curved outer surface and escapes through two circular openings in the outer bases. Flow between curved walls is approximated by one between parallel planes $z = \pm b$. The Navier-Stokes equations are simplified to $\partial p/\partial x = \mu\partial^2 v_x/\partial z^2$, $\partial p/\partial y = \mu\partial^2 v_y/\partial z^2$, $p = p(x, y)$ which imply $2\mu v_x = (z^2 - b^2)\partial p/\partial x$, and a similar form for v_y. For a barotropic flow with $\rho = f(p)$ one finds from the equation of continuity that $P(x, y) = \iint dp$ is harmonic. Its conjugate harmonic function is essentially a stream function, so the standard complex-variable techniques of plane incompressible flow can be applied. The effects of entrance slits are represented by periodically arranged sources on lines parallel to the x-axis. Since P is required to be constant on $y = \pm a$, $P + i\psi$ can be expressed in terms of sums of logarithms of Jacobian elliptic functions. The flows between the two bases are represented by logarithmic (sink) potentials. Formulas are developed to express base pressures and exit rates of mass flows to entrance pressures and entrance rates of mass flow.

J. H. Giese, USA

2360. Hoshizaki, H., and Smith, H. J., The effect of helium injection at an axially symmetric stagnation point, *J. Aero/Space Sci.* **26,** 6, 399–400 (Readers' Forum) June 1959.

2361. Stark, V. J. E., A method for solving the subsonic problem of the oscillating finite wing with the aid of high-speed digital computers, SAAB Aircr. Co., Linköping TN 41, 36 pp., Dec. 1958.

An attempt is made to formulate the linearized, subsonic problem of the oscillating finite wing in such a way that its solution can be obtained with the aid of high-speed digital computers. An integral equation for a special function, the integrated acceleration potential, is formulated. The solution is approximated by a linear combination of members in a set of functions, chosen on the basis of two-dimensional theory. For the calculation of the downwash induced by the pressure distributions pertaining to each of these functions, a straightforward method is developed through dividing the field of integration into a relatively large number of square boxes and expanding the functions in series of orthogonal polynomials in each of these boxes. The numerical results presented, for a rectangular wing of aspect ratio 3 and incompressible flow, were obtained through approximating the given downwash in the sense of the least square method. With coefficients thus determined, a linear combination of the above mentioned functions is found which approximates the solution of the integral equation.

From author's summary by R. C. Roberts, USA

2362. Stivers, L. S., Jr., Effectiveness of an all-movable horizontal tail on an unswept-wing and body combination for Mach numbers from 0.60 to 1.40, NASA TN D-13, 23 pp., Aug. 1959.

The wing was mounted high on the body at a position 0.12 wing semispans above the plane of the horizontal tail, which was mounted on the body center line. The wing had an aspect ratio of 3.09, and the horizontal tail, an aspect ratio of 3.99. Lift, drag, and pitching-moment coefficient were determined. The Reynolds number of the data is 1.5 million. The effective downwash characteristics at the horizontal tail were evaluated and are presented. Calculated life and pitching-moment curve slopes and effectiveness of the horizontal tail were determined.

From author's summary

2363. Taylor, R. A., Transonic aerodynamic characteristics of several bodies having elliptical cross sections and various plan forms, NASA TN D-14, 31 pp., Aug. 1959.

Measured force characteristics are presented for bodies with elliptical cross sections whose major to minor axis ratios are 3 and 4 and whose lengths are 58, 72, and 85% of the closure length. The axial distribution of cross-sectional area is that of a parabolic-arc body of revolution of fineness ratio 12. The bodies were tested through an angle-of-attack range from $-2°$ to $+12°$ and through a Mach number range from 0.40 to 1.20.

From author's summary

2364. Knechtel, E. D., Experimental investigation at transonic speeds of pressure distributions over wedge and circular-arc airfoil sections and evaluation of perforated-wall interference, NASA TN D-15, 84 pp., Aug. 1959.

Pressure distributions were measured at transonic speeds for several single-wedge, double-wedge, and circular-arc airfoils to provide comparisons with available transonic theory, to indicate the existence of perforated-wall interference, and to show the effects of airfoil geometry and of surface roughness. The results indicated the presence of an open-jet-type interference at transonic speeds, qualitatively confirming recent theoretical results.

From author's summary

2365. Hammond, A. D., and McKinney, L. W., Investigation at transonic speeds to determine lateral control effectiveness of blowing laterally over surfaces of 30° and 45° swept wings, NASA TN D-42, 53 pp., Oct. 1959.

This investigation was made on two semispan wings having quarter-chord-line sweep angles of 30° and 45°; each wing had an aspect ratio of 4, a taper radio of 0, and an NACA 65A004 airfoil section. Tests were made at Mach numbers from 0.60 to 1.10 for the 30° and 45° swept wings through an angle-of-attack range from $-16°$ to 16° and $-20°$ to 20°, respectively. The basic data are presented in tabular form and the partial derivatives of the force and moment coefficients with respect to momentum coefficient are presented in graphic form. A limited discussion of the effects of lateral blowing on the rolling-moment characteristics is presented.

From authors' summary

2366. Mugler, J. P., Jr., Basic pressure measurements at transonic speeds on a thin 45° sweptback highly tapered wing with systematic spanwise twist variations—wing with cubic spanwise twist variation, NASA Memo 5-12-59L, 148 pp., June 1959.

Pressure data are presented which were obtained in the Langley 8-ft transonic pressure tunnel. Tests were made at Mach numbers from 0.800 to 1.200 at stagnation pressures of 1.0 and 0.5 atmosphere and at angles of attack from $-4°$ to 12°. The wing has 45°

sweepback of the quarter-chord line, taper ratio of 0.15, and an aspect ratio of 4. The wing was cambered and had a thickened root section. From author's summary

2367. Kawamura, R., and Karashima, K., Experimental investigation of transonic flow past two-dimensional biconvex circular-arc airfoils at small angles of attack, Aero. Res. Inst., Tokyo University, Rep. 342, 19-42, Apr. 1959.

Airfoils with thickness-chord ratios of 10.6, 8.08 and 5.44 per cent and chord length of 20 mm have been investigated. Aerodynamic characteristics of the airfoils have been calculated from the surface pressure distributions obtained by a Mach-Zehnder interferometer. Most of the results confirm the validity of the transonic similarity rule. The Reynolds number was low, in reference to the chord length about 40,000. The results were obtained with laminar boundary layer. E. Petersohn, Sweden

2368. Briggs, B. R., Calculation of supersonic flow past bodies supporting shock waves shaped like elliptic cones, NASA TN D-24, 30 pp., Aug. 1959.

Author considers steady adiabatic supersonic flows of ideal gases across shock waves shaped like elliptic cones. Numerical solutions of the *exact* equations are given for values of gas constant corresponding to various real gases. From solutions, shapes of obstacles in flow are deduced.

B. Bernstein, USA

2369. Hammitt, A. G., and Murthy, K. R. A., Approximate solutions for supersonic flow over wedges and cones, AFOSR TN 59-304 (Princeton Univ., Dept. Aero. Engng. Rep. 449; ASTIA AD 213 088), 20 pp., Apr. 1959.

Exact expression of the shock-wave angle is given directly in terms of wedge angle for two-dimensional case. Approximate solutions for supersonic flow around a cone are obtained by series expansion with the difference between conical ray angle θ and cone surface angle θ_c, i.e. $b = \theta - \theta_c$. Boundary conditions are satisfied at the shock cone surface up to the order of b^3 or b^2. Shock angle, surface pressure and surface Mach number are given in analytical forms, which show good results for $M > 3$ and $\theta_c > 10^\circ$. The method can be applied to a wide range of Mach number, cone surface angle and specific heat ratios, since accuracies are governed by b only.

S. Uchida, Japan

2370. Chu, S. T., and Lee, J. D., Steady state fusible body shapes in a heated supersonic stream and hypersonic stream, Proc. Sixth Midwest. Conf. Solid Mech., Austin, Texas, Sept. 1959; Austin, Tex., Univ. Press, 1959, 71-80.

2371. Carafoli, E., and Sandulescu, S., Harmonic oscillations of ailerons of general form in supersonic flow (in French), *Arch. Mech. Stos.* **10**, 6, 771-782, 1958.

Autnors discuss the supersonic flow around a triangular wing whose points oscillate harmonically as an effect of a variable in time warp of the wing, or of an oscillating motion around an axis situated in the wing plane.

As is known, for the case of low frequency motions the problem reduces to the study of high-order conical motions whose solution may be readily found by using the general formulas obtained in a previous paper [AMR **11**(1958), Rev. 4629].

The problem of harmonic oscillations of polygonally shaped ailerons about their hinge is particularly discussed. In this case the solution is obtained by studying the oscillating motion of two conveniently chosen triangular surfaces. Expressions are given which define the pressure coefficients for ailerons with subsonic and supersonic leading edges. Results may be easily extended to triangular and trapezoidal ailerons.

St. Savulescu, Roumania

2372. Martellucci, A., An extension of the linearized characteristics method for calculating the supersonic flow around elliptic cones, AFOSR TN 59-632 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech. Rep. 517), 51 pp., June 1959.

Author considers the prediction of the flow properties for non-slender elliptic cones, inclined to the flow at high velocities. In this paper the author extends the method presented by A. Ferri in NACA TN 2515, 1951, and by A. Ferri, N. Ness, and T. Kaplita in *J. Aero. Sci.* **20**, Aug. 1953.

Author places special emphasis on extending the technique to large angle of attack. Principally his method consists of the superposition of linearized flow solutions upon the solution of the nonlinear flow around a circular cone. The equations that define the velocity components of the linearized flow fields are solved by step-by-step numerical procedure. This modified technique is applied to obtain the surface pressure distribution on several elliptic cones. The method is extended to predict the pressure distribution on conical bodies at angles of attack. Experimental results were obtained for some cones at $M_1 = 3.09$ and 6.0, and comparison with theory is made. T. Riabokin, USA

2373. Johnson, R. H., Instability in hypersonic flow about blunt bodies, *Physics of Fluids* **2**, 5, 526-532, Sept./Oct. 1959.

Paper describes experimental study of helium flow about blunt bodies with leading-edge cavities, at Mach numbers about 22. The shock waves are in erratic and violent motion, in which no periodicity is detected. With some cavity shapes instability occurs naturally; with others it is provoked by injecting a slow flow of gas into the cavity.

Author gives a rather vague account of the mechanism in terms of formation and ejection of vortices. Possible effects of unsteady flow on heat transfer are discussed, and author suggests that in some conditions existing cavities may become deeper, and this may explain formation of pits on meteorites. Greatest value of the paper may be in suggesting several lines on which further useful work could be done. L. H. Tanner, England

2374. Williams, H., Hypersonic conical flow, *ARS J.* **29**, 9, 668-670 (Tech. Notes), Sept. 1959.

The analysis presents an approximate solution for hypersonic flow about a semi-infinite cone at zero angle of attack. Simple expressions for surface velocity, pressure and temperature ratios are derived and compared with those calculated by Kopal.

From author's summary

2375. Wan, K.-S., On an exact solution of incompressible, inviscid, hypersonic, stagnation-point flow for a sphere, *J. Aero/Space Sci.* **26**, 11, 755-756 (Readers' Forum), Nov. 1959.

The purpose of this note is to present an exact solution for an inviscid hypersonic flow at the stagnation point of a sphere. The density ρ of the flow in the "shock layer" is assumed to be constant and is equal to $\rho/\rho_\infty = 1/k$ where the value of k depends on the free-stream Mach number M_∞ and the ratio of the specific heats $\gamma = C_p/C_v$. From author's summary

2376. Cornog, R., Some economic aspects of hypersonic flight, *ARS J.* **29**, 10, 706-715, Oct. 1959.

An examination is made of the influence of various flight performance characteristics on the direct flying costs of commercial aircraft whose average cruising speed is more than 1 mile per sec. Two types of aircraft are considered: Boost-glide vehicles and vehicles which cruise at constant speed. It is found that at hypersonic speeds, new features of flight operation become important. For example, for both types of vehicles, an important technical problem and economic factor is the initial acceleration to flying speed, which immediately follows takeoff. It is estimated that, granted reasonable extrapolations of contemporary technology, both

types of vehicles may be expected to have total direct flying costs of less than 10 cents per ton-mile. From author's summary

2377. Henderson, A., Jr., and Johnston, P. J., Fluid-dynamic properties of some simple sharp- and blunt-nosed shapes at Mach numbers from 16 to 24 in helium flow, NASA Memo 5-8-59L, 63 pp., June 1959.

Flat plates, 5° and 10° wedges, and 5° and 10° cones were investigated. The flat-plate results are for a leading-edge Reynolds number range of 584 to 19,500 and show that the indices pressure distribution is essentially linear with the hypersonic viscous interaction parameter $\bar{\chi}$ within the scope of this investigation. It is also shown that the rate at which the induced pressure varies with $\bar{\chi}$ is a linear function of the leading-edge Reynolds number. The wedge and cone results show that as the flow-deflection angle increases, the induced-pressure effects decrease and the measured pressures approach those predicted by inviscid shock theory.

From authors' summary

2378. Kim, C.-S., Experimental studies on the hypersonic flow past plane, convex and concave wedges, *J. Phys. Soc. Japan* **14,** 6, 827-837, June 1959.

In this paper, the phenomena of viscous-inviscid interaction effects at $M_\infty = 6.2$ over the front part of bodies have been investigated. The models tested are a flat plate and wedges having a plane, a convex or a concave surface, respectively. A uniform flow of $R_\infty = 2.0 \times 10^6$ per cm was established using a divergent shock tube. The measurements of the flow field were made by optical methods (interferometer and schlieren photograph), and in order to supplement the data the x-ray technique was employed near the leading edge of the model.

The results are as follows. (1) For a flat plate: (i) the pressure distribution on the sharp-nosed plate is about 5% higher than Nagakura-Naruse's theoretical values; (ii) the boundary-layer thickness agrees almost perfectly with Naruse's theoretical values; (iii) the shock-wave location is in good agreement with the empirical formulas of Kendall and of Bogdonoff and Hammitt. (2) For wedges: (i) near the leading edge, the boundary-layer growth on a concave wedge is more rapid than that on either a plane or a convex wedge; (ii) except in the region close to the leading edge, the influence of leading-edge bluntness on boundary-layer growth is significant in the order of convex wedge, plane wedge and concave wedge; (iii) except in the region very close to the leading edge, the pressure distributions at the front parts of the plane and convex wedges are in fairly good agreement with the values predicted by inviscid theories (characteristic method, tangent-wedge approximation, Newtonian-plus centrifugal-force approximation and hypersonic small-disturbance theory), but considerable discrepancies are found at the rear parts; (iv) for the concave wedge, agreement is rather better at the rear part of the body than at its front part. From author's summary

2379. Freeman, N. C., On a singular point in the Newtonian theory of hypersonic flow, AFOSR TN 59-635 (Princeton Univ., Dept. Aero. Engng. Rep. 466), 28 pp., May 1959.

Newtonian theory, including centrifugal forces, predicts zero pressure at some point on the windward side of a body in hypersonic flow, and higher approximations become infinite there. Author makes a local examination of this singularity for the sphere (where it occurs at 60° from the nose). By introducing new variables stretched by suitable powers of $\varepsilon = (\gamma - 1)/(\gamma + 1)$, he finds a uniformly valid first approximation that joins the usual Newtonian solution smoothly to a free layer. The theory depends on ε^{A_1} being small, which is never satisfied in practice. For this reason only qualitative experimental confirmation is found for an interesting prediction that surface pressure should vary as the inverse 3/2-power of the distance between body and shock.

M. D. Van Dyke, USA

2380. Freeman, N. C., On the Newtonian theory of hypersonic flow for a blunt body, AFOSR TN 59-634 (Princeton Univ., Dept. Aero. Engng. Rep. 467), 14 pp., May 1959.

The Newtonian approximation of Freeman and Chester [AMR **10** (1957), Revs. 3704, 3696] applies to a "bluff" body (e.g., a sphere) but not to a "blunt" body (e.g., a disk) whose surface is everywhere almost normal to the stream. Here a systematic expansion scheme in powers of $(\gamma - 1)/(\gamma + 1)$ is introduced for treating bodies of the latter type at infinite Mach number. The first approximation is shown to reproduce results of Hayes and of Serbin [cf. Hayes and Probstein, "Hypersonic flow theory," Academic Press, 1959, chap. 5]. M. D. Van Dyke, USA

2381. Einbinder, H., A note on blast-wave theory, *J. Aero/Space Sci.* **26,** 3, 191-192 (Readers' Forum), Mar. 1959.

Blast-wave theory, for frictionless hypersonic flow, is applied to the case of a blunt-nosed body, such as a hemispherically capped cylinder. Because of the complex interaction that occurs between the body and the shock front, blast-wave theory fails to provide an adequate description of the hypersonic flow around blunt-nosed slender bodies. The presence of such interaction is demonstrated by the characteristic lines which are reflected a number of times between the body and the shock front in passing from the stagnation region downstream.

R. C. Binder, USA

2382. Lapworth, K. C., An experimental investigation of the stability of plane shock waves, *J. Fluid Mech.* **6,** 3, 469-480, Oct. 1959.

Deformation of shock waves passing over and downstream of wedges in a shock tube were studied at three Mach numbers (1.2, 1.4, 1.6). Comparison with Freeman's [*J. Fluid Mech.* **6,** 3, 469-480, Oct. 1959] linearized theory for approach to plane shape indicates good perturbation decay rate predictions but larger amplitudes. Disagreement beyond four channel widths aft of wedge was attributed to wakes from the wedge apex.

J. R. Baron, USA

2383. Gundersen, R., A perturbation analysis of shock flow in a nozzle, *J. Aero/Space Sci.* **26,** 11, p. 763 (Readers' Forum), Nov. 1959.

By the use of a linearization based on small area variations, the motion of a plane shock generated by a uniform compressive piston motion has been previously solved for the case of a slowly converging or diverging one-dimensional channel. In the present paper, these results are extended to the case where the channel presents a throat. From author's summary

2384. Markstein, G. H., Graphical computation of shock and detonation waves in real gases, *ARS J.* **29,** 8, 588-590 (Tech. Notes), Aug. 1959.

The conservation relations across a shock or detonation wave are represented in the form of a graph applicable to real gases of arbitrary composition. Computation of shock waves reflected from a closed end is performed by means of another universally applicable graph.

From author's summary by A. E. Seigel, USA

2385. Makushkin, V. P., and Mishuev, A. V., Spherical barium titanate pressure pickups for shock waves in air, *Soviet Phys.-Acoustics* **5,** 1, 62-67, Aug. 1959. (Translation of *Akust. Zh., USSR* **5,** 1, 64-70, Jan./Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

The present article sets forth an analysis of the operation of a spherical barium titanate piezoelectric shell. It gives a basis for the selection of the shell thickness. It describes the construction of a spherical pressure pickup of radius 1.9 mm with a holder designed for quenching elastic waves. It gives the results of testing

in air shock waves with a pressure at the front of 0.025–3.5 kg/cm². It determines the conditions for undistorted recording of the behavior in the wave. From authors' summary

2386. Rosciszewski, J., Influence of shock-wave attenuation by boundary-layer growth on contact-surface motion in a shock tube, *J. Aero/Space Sci.* **26,** 6, 388–389 (Readers' Forum), June 1959.

It is shown that for a nonsteady, nonisentropic flow behind a shock wave the contact surface can be accelerated by an attenuated shock wave, in accordance with experimental evidence [AMR **10** (1957), Rev. 2664]. However, no numerical data are given.

C. B. Ludwig, USA

2387. Szaniawski, A., The structure of weak shock waves in real gases (in English), *Arch. Mech. Stos.* **11,** 2, 173–192, 1959.

The starting point of these consideration is a critical analysis of the existing methods for calculating the thickness of the shock wave; experimental results show that for the majority of real gases the thickness of the shock wave is greater that the calculated value. The cause of this discrepancy is attributed by the author to the fact that the relaxation phenomenon is not taken into account (the relaxation time—the time necessary for attaining thermodynamic equilibrium).

Author considers the structure of a weak shock wave, that is, a wave of which the velocity of propagation is slightly greater than the sound velocity. He assumes that the gas is quasi-perfect, that is, it satisfies the Clapeyron equation only in an approximate manner (the second virial coefficient being taken into consideration in the equation of state). In addition the viscosity (also the volume viscosity) is taken into account as well as the heat conductivity with variable specific heat C_v, the internal degrees of freedom and the relaxation phenomena involved. Author takes into account the fact that each degree of freedom is characterized by a different relaxation time. Assuming the constancy of the coefficient of viscosity and heat conduction and one-dimensional flow, author uses the equation of motion derived in his previous paper. Expressing the equations in dimensionless form and expanding the flow parameters in terms of wave intensity, the equations of motion are simplified.

In this way the author obtains an equation for the thickness of a weak shock wave. From this equation he concludes that the influence of the second virial coefficient in the equation of state, the Prandtl number and the volume viscosity on the wave thickness is insignificant.

The influence of the relaxation and the variability of the specific heat is not investigated in this paper. Another paper by the same author is being devoted to this subject (see following review).

J. Rosciszewski, Poland

2388. Szaniawski, A., The influence of molecular structure on the structure of a weak shock wave (in English), *Arch. Mech. Stos.* **11,** 3, 317–332, 1959.

This is a continuation of another paper by the same author published in the preceding number of the same journal (see preceding review). Its object is to discuss the influence of the relaxation phenomenon and the variability of the specific heat on the thickness of a weak shock wave. In the analysis of the relaxation phenomenon three independent groups of degrees of freedom are considered: the translational, rotational and vibrational group.

The influence of each group of degrees of freedom on the thickness of the shock wave is analyzed numerically on the basis of the data known from the literature. These data, concerning the number of intermolecular collisions necessary for the attainment of the state of equilibrium, vary in a broad range. Hence the difficulty of a more accurate appraisal of the relaxation phenomenon.

The author states that the influence of relaxation is considerable and that the disregard of this phenomenon leads to errors, which, in the case of diatomic gases, may considerably exceed 100%.

For multiatomic gases this error may be ever greater.

The author finds that for molecules composed of not more than five atoms the influence of the variation of the specific heat is small. He expresses the opinion that for molecules of more than five atoms this influence will probably also be insignificant.

J. Rosciszewski, Poland

2389. Sidorkina, S. I., Certain problems of the propagation and effects of shock waves (in Russian), Avtoref. Diss. Kand. Fiz.-Matem. Nauk, MGU, Moscow, 1957; *Ref. Zh. Mekh.* no. 7, 1958, Rev. 7435.

2390. Jarre, G., The dissociation of a pure diatomic gas behind a strong normal shock wave, AFOSR TN 58–7 (Lab. Meccanica Applicata Politecn. Torino, TN 3; ASTIA AD 148 046), 14 pp. + 4 figs., Nov. 1957.

The equilibrium state of a pure dissociating diatomic gas behind a strong shock is discussed. A simplified model, in which the vibration of the molecules is supposed to be only half-excited, leads to results which are the same as those obtained by Lighthill [AMR, **5** (1952), Rev. 2568]. The dissociation rate in the nonequilibrium region is then examined. Estimates of the length of the relaxation zone are made by assuming the reaction to be isenthalpic and the length to be essentially controlled by the final approach to equilibrium. F. A. Goldsworthy, England

2391. Riazanov, E. V., Constructions of exact solutions of the equations of gas dynamics in the presence of discontinuities, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22,** 5, 1020–1021, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Paper presents a new analytical method for obtaining some special classes of solutions for self-similar gas flows with shock waves. L. Trilling, USA

2392. Takao, K., Dynamics of rarefied gases: Part I, Fundamental equations, *Trans. Japan Soc. Aero. Engng.* **1,** 1, 2–8, 1958.

In order to treat the flow of a gas near a wall, the author considers two distribution functions, one for molecules not yet reflected and another for reflected molecules. A corresponding separation is made in the collision integrals occurring in the first few equations of moments. It is assumed that a specified fraction n of the incident molecules is perfectly reflected while the remainder is absorbed and re-emitted with a Maxwellian distribution at the temperature of the wall. After further approximations, involving use of distribution functions supposed expressible to terms of the first five moments, there result certain moment equations of the Maxwell-Grad type modified by terms arising from the assumed law of reflection. C. Truesdell, USA

2393. Schaaf, S. A., Recent progress in rarefied gas dynamics research, Proc. Sixth Midwest. Conf. Fluid Mech., Austin Texas, Sept. 1959; Austin, Tex., Univ. Press, 1959, 1–15.

2394. Muench, J., Supersonic flow past oscillating bodies of revolution with a frequency not necessarily small (in English), AFOSR TN 59–452 (Math. Inst., Technische Hochschule Munchen, Munich, Germany, TN 8; ASTIA AD 215 027), 13 pp., June 1959.

Author gives a representation of the potential of linearized flow past bodies of revolution executing elliptic oscillations of arbitrary frequency. The potential is given in terms of Bessel and Legendre functions. A generalization of the method due to von Karman and Moore is given for the case of a body of revolution not necessarily oscillating slowly.

From author's summary by J. N. Aguirre, Argentina

2395. Yang, K.-T., Unsteady laminar compressible boundary layers on an infinite plate with suction or injection, *J. Aero/Space Sci.* **26,** 10, 653–662, Oct. 1959.

An integral solution for the general case, and an exact solution applicable only to certain specific unsteady free-stream and surface suction or injection variation, are presented. Qualitative conclusions of the unsteady effects of free-stream velocity and surface suction or injection on laminar boundary-layer behavior are made.

From author's summary by A. N. Petroff, USA

Boundary Layer

(See also Revs. 2348, 2355, 2386, 2395, 2459, 2465, 2505, 2510, 2511, 2512, 2515, 2519, 2533, 2534, 2655)

2396. Rosenzweig, M. L., The response of laminar boundary layer to impulsive motions, AFOSR TN 59-92 (Cornell Univ., School Aero. Engng.; ASTIA AD 210 182), 96 pp., Feb. 1959.

A theoretical analysis is presented for two-dimensional stagnation-point flow against a wall which moves impulsively in its own plane. Author shows that the equation describing the flow is linear, and uses Laplace transform techniques to obtain a solution. This is done in a novel manner by obtaining series solutions for the transform function which are applicable both for large and small values of the transform variable. These limiting series solutions are in turn employed to construct an approximate expression which is easily inverted.

Author further investigates other types of linearized nonsteady boundary-layer flows. Solutions based on Lighthill's method are presented for flow about cylinders of arbitrary cross section. Alternate results are given for wedge flows.

Reviewer believes that author's method of constructing approximate solutions by use of series expansions in terms of the Laplace transform variable is quite valuable, and has wide applicability to other types of linear nonsteady boundary-layer problems. In fact, this method has recently been applied with good success to boundary-layer heat transfer with a nonsteady surface temperature.

R. Cess, USA

2397. Walz, A., Compressible turbulent boundary layers with heat transfer and pressure gradient in flow direction, *J. Res., Nat. Bur. Stands.* **63** B (*Mathematics and Mathematical Physics*), 1, 53–70, July/Sept. 1959.

The steady-state continuity, momentum, and energy equations were reduced to two infinite systems of ordinary differential equations with a twice infinite number of unknowns. These infinite systems are shown to include the von Karman-Pohlhausen momentum integral and Weighardt's energy integral. Author shows that as one uses a set of equations, other than the zero-th set in the infinite system, their representation of the boundary layer becomes poorer as the order of the set increases ($\pm 1, \pm 2, \ldots \pm\infty$). The only initial distinction between laminar and turbulent flow is through the author's use of an effective coefficient of viscosity. Author then formulates law of dissipation and turbulent wall friction from empirical relationships and physical arguments. Author, taking the zero-th set of the infinite system, defines five "universal" functions in terms of three parameters: velocity form and heat transfer parameters and free-stream Mach number. By linearizing the effect of the heat transfer parameter in the "universal" functions, author presents examples including heat and no-heat transfer. Within a given range of *Re* number, comparison with experiments is good. He also shows effect of negative pressure gradient and wall cooling on turbulent separation point.

F. L. Schuyler, USA

2398. Wu, C.-S., The three-dimensional incompressible laminar boundary layer on a spinning cone, *Appl. Sci. Res.* (*A*) **8,** 2/3, 140–146, 1959.

Flow of incompressible fluid due to rotation of an infinite disk has been treated by von Karman and Cochran. Author shows that this analysis carries over to a spinning cone. The only difference lies in pressure gradient across boundary layer due to centrifugal forces, but this influence is of a higher order in the boundary-layer thickness. Nevertheless the centrifugal would ultimately cause a separation of flow.

K. G. Guderley, USA

2399. Libby, P. A., and Visich, M., Jr., The law of the wake in compressible turbulent boundary layers, *J. Aero/Space Sci.* **26,** 8, 541–542 (Readers' Forum), Aug. 1959.

2400. van der Bliek, J. A., Boundary layer transition on a 10-degree cone in the N. A. E. 30- × 16-inch wind tunnel, Nat. Aero. Establ., Canada, Lab. Rep. LR-232, 13 pp., Nov. 1958.

Boundary-layer transition on a 10-degree cone is visualized by three equivalent evaporation methods (fluorescent lacquer technique, French chalk and kerosene, lamp-black and kerosene). The transition Reynolds number ($2.3 \times 10^6 < R_e < 3.3 \times 10^6$) is plotted versus Mach number or Reynolds number per unit length. No trend is shown with respect to these two parameters in the narrow ranges tested ($1.46 < M < 2.03$ and $3.8 \times 10^6 < R_e$ per foot $< 4.3 \times 10^6$). The data are compared to results on transition location on 10-degree cones in 8 different NACA wind tunnels, thus showing the strong influence of the turbulence level of the tunnel stream and other flow disturbances on transition location. The base pressure is measured at $M = 0.39$ and $M = 2.03$ for different positions of a transition wire along the cone. The wire tends to decrease the base pressure. This tendency decreases as the wire is moved toward the apex, and it would seem that in advance of a certain position the wire ceases to influence the base pressure, the latter being then that observed with natural transition. The base pressure coefficient with natural transition decreases with increasing Mach number.

E. A. Brun, France

2401. Braslow, A. L., Knox, E. C., and Horton, E. A., Effect of distributed three-dimensional roughness and surface cooling on boundary-layer transition and lateral spread of turbulence at supersonic speeds, NASA TN D-53, 40 pp., Oct. 1959.

An investigation was made in the Langley 4- by 4-ft supersonic pressure tunnel at Mach numbers of 1.61 and 2.01 to determine (1) the effect of distributed roughness on boundary-layer transition with the model surface at adiabatic wall temperature and cooled and (2) the effect of surface cooling on the lateral spread of turbulence. Both distributed granular-type and single spherical roughness particles were used, and transition of the boundary layer was determined by hot-wire anemometers. The transition-triggering mechanism of the three-dimensional roughness at supersonic speeds appeared to be the same as that previously observed at subsonic speeds. In fact, the critical value of the roughness Reynolds number parameter $\sqrt{R_{k,t}}$ (that is, the value at which turbulent spots are initiated by the roughness) was found to be approximately the same at supersonic and subsonic speeds when complete local conditions at the top of the roughness, including density and viscosity, were considered in the formulation of the roughness Reynolds number. For three-dimensional roughness at a Reynolds number less than its critical value, the roughness introduced no disturbances of sufficient magnitude to influence transition. Surface cooling, although providing a theoretical increase in stability to small disturbances, did not increase to any important extent the value of the critical roughness Reynolds number for three-dimensional roughness particles. Cooling, therefore, because of its effect on the boundary-layer thickness, density, and viscosity actually promoted transition due to existing three-di-

mensional surface roughness for given Mach and Reynolds numbers. The measured lateral spread of turbulence in the boundary layer appeared to be unaffected by the increased laminar stability derived from the surface cooling.

From authors' summary

2402. McTigue, J. G., Overton, J. D., and Petty, G., Jr., Two techniques for detecting boundary-layer transition in flight at supersonic speeds and at altitudes above 20,000 feet, NASA TN D-18, 30 pp., Aug. 1959.

The location of transition was measured on a supersonic fighter-type airplane by resistance-thermometer and sublimation techniques. Application of these techniques required the use of only the external surface without disturbing the internal structure. Agreement between the two methods as achieved throughout this program is discussed. Also presented are possible extensions of the program to higher Mach numbers. From authors' summary

2403. Feldman, S., On the instability theory of the melted surface of an ablating body when entering the atmosphere, *J. Fluid Mech.* **6,** 1, 131-155, July 1959.

Author discusses the possible mechanisms for instability. He concludes that in practical cases, i.e., low liquid flow rates, the instability is essentially of the Lamb-Taylor type. The analysis is carried out by assuming that the gas density is negligible compared to the liquid density and that the disturbance velocities are small so that the equations may be linearized. Solutions are obtained for two specific incompressible flow problems. The amplification factor and most amplified wavelength are calculated for both problems. In the first problem, where the viscosity increases exponentially with distance from the interface, and the liquid layer is taken to be semi-infinite in extent, it was found that small amplification rates depend critically on having large viscosity and surface tension and a rapid change of viscosity with distance. In the second problem, it is assumed that the viscosity is constant and that the liquid layer has a finite depth. In this case it was again found that large viscosity is desirable. Decreasing the depth of the liquid layer was found to have a stabilizing influence. The effect of variable deceleration during atmospheric entry is included in the analysis. A brief discussion is presented in which it is indicated that the markings observed on meteorite fragments are consistent with the type of instability investigated.

M. Epstein, USA

2404. Gribben, R. J., Laminar boundary layer with suction and injection, *Physics of Fluids* **2,** 3, 305-318, May-June 1959.

With the assumptions of a heat-insulated body, a Prandtl number of unity and a linear temperature-viscosity relation, the axisymmetric equations governing a given high-speed compressible flow are reduced to the equations describing an incompressible two-dimensional flow past a flat plate with a determinable main stream and normal wall velocity distribution. The results are applied to the supersonic flows over a cone with wall velocities proportional (1) to the first power and (2) to the inverse-half-power of distance along a generator when the resulting incompressible flows are known. Also the flow near the tip of a general slender body of revolution in supersonic flow with constant wall velocity is obtained by solving numerically the equations of the correlated incompressible flow. It is also shown that, if the assumption of an insulated body is discarded, a given high-speed compressible flow may still be correlated with a determinable low-speed compressible flow. From author's summary by H. Gortler, Germany

2405. Taylor, E. S., The skewed boundary layer, *Trans. ASME* **81** D (*J. Basic Engng.*), 3, 297-304, Sept. 1959.

The geometry of the skewed boundary layer is described, and two methods of producing it are discussed. Experimental results show that the form of the usual skewed boundary layer is a thin collateral sublayer under a quasi-collateral outer region. The geometry of separation of a skewed boundary layer is discussed. It is concluded that separation of a skewed boundary layer may differ radically from that of a collateral boundary layer and that separation criteria used for collateral boundary layers may give misleading results when applied to skewed boundary layers. It is concluded that the understanding of the skewed boundary layer can contribute to improved design of turbomachinery.

From author's summary

2406. Ginevskii, A. S., and Solodkin, E. E., The effect of lateral surface curvature on the characteristics of axially-symmetric turbulent boundary layers, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 6, 1169-1179, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Authors consider incompressible, viscous, longitudinal flow about body of revolution or in axially-symmetrical diffusers. They solve momentum and continuity equation for mean flow in boundary layer by expanding term $r\tau$ in neighborhood of the surface in a Maclaurin series, giving result that "... the laws of shear stress in the vicinity of convex and concave surfaces are described by the same equation." Mixing length is taken proportionally to distance from wall and resulting integrated equations give velocity profile in turbulent boundary layer on both concave and convex surfaces. Parameters considered are longitudinal pressure gradient, lateral curvature, position on body. Equation is derived for local and total drag coefficients and results applied to plane curvilinear surfaces, cylinders, slightly diverging ducts, and flat plates. Results show that axially-symmetrical turbulent boundary layer is more full on convex surface and less full on concave surface than on flat plate. Equations indicate that "... lateral curvature of a convex surface alters the form of the velocity profile and frictional drag coefficients in the same direction as a negative longitudinal pressure gradient." Experimental values of the friction coefficient on long cylinders agree with values computed from the theory. J. G. Knudsen, USA

2407. Burns, J. G., Childs, W. H. J., Nicol, A. A., and Ross, M. A. S., Development and use of a vane device for boundary-layer measurements, *J. Fluid Mech.* **6,** 1, 97-112, July 1959.

Hinged vanes, roughly 1 cm square by 0.001 in. thick, and a sensitive electrical system for recording the motion of the vane have been developed for the observation of fluctuating y-components of velocity in boundary layers. An approximate theory of the natural oscillations of such vanes is presented and experimentally verified. Using vanes as resonant detectors, measurements have been made of oscillations injected into the laminar boundary layer on a flat plate in a wind tunnel with 0.3% free-stream turbulence. Points on the neutral Tollmien-Schlichting curve have thereby been obtained which lie close to the theoretical neutral curve. A. M. O. Smith, USA

2408. Norbury, J. F., Some measurements of boundary-layer growth in a two-dimensional diffuser, *ASME Trans.* **81** D (*J. Basic Engng.*), 3, 285-296, Sept. 1959.

Low-speed experiments were carried out in a two-dimensional diffuser having a square throat and an area ratio of two to one. Measurements were made of static pressure distribution, velocity contours at throat and outlet, and boundary-layer growth along the four wall center lines. Visual flow experiments were performed using tufts and smoke filaments. Similar experiments were carried out with the throat boundary layers artificially thickened by means of round rods placed on the walls upstream. Disparities between the measured growth of momentum thickness and that predicted by the simple momentum equation are discussed, as well as the effect of the artificial thickening on diffuser efficiency.

From author's summary

2409. Martin, J. A., Determination of local skin friction by means of surface total-pressure probes, *J. Aero/Space Sci.* **26,** 5, p. 320 (Readers' Forum), May 1959.

2410. Gouse, S. W., Jr., Brown, G. A., and Kaye, J., Preliminary results of measurement effects of diffusion of helium into the laminar boundary layer of a supersonic flow of air in a tube at Mach 5, *J. Aero/Space Sci.* **26,** 8, 533–535 (Readers' Forum), Aug. 1959.

Turbulence

(See also Revs. 2386, 2397, 2406, 2407, 2623)

2411. Jain, P. C., A theory of homogeneous isotropic turbulence, *Appl. Sci. Res.* (*A*) **8,** 2/3, 219–227, 1959.

Homogeneous and isotropic turbulence is discussed in the present paper. An attempt has been made to find the simplifying hypothesis for connecting the higher-order correlation tensor with the lower ones. Starting from the Navier-Stokes equations of motion for an incompressible fluid and following the usual method of taking the averages, a differential equation in Q and X, the defining scalar of the second-order correlation tensor Q_{ij} and the defining scalar of a third-order isotropic tensor X_{ijk}, has been derived. The tensor X_{ijk} stands for a tensorial expression containing the derivatives of the third- and the fourth-order tensors. Then the hypothesis is used that $X = F(Q)$, where F is an unknown function. To find the forms of F, Kolmogoroff's similarity principles have been used, and thus two forms for $F(Q)$ corresponding to two regions of the validity of these principles have been deduced.

From author's summary by L. S. G. Kovasznay, USA

2412. Squire, W., A unified theory of turbulent flow, Part I: Formulation of the theory, *Appl. Sci. Res.* (*A*) **8,** 2/3, 158–168, 1959.

Author attempts to present a reformation of the Reynolds equations in light of Broszko's work. Using the author's own words, it is more a prospectus than a definite theory.

L. S. G. Kovasznay, USA

2413. Ohji, M., On the theory of homogeneous axisymmetric turbulence. Part II, *Rep. Res. Inst. Appl. Mech. Kyushu Univ.* **6,** 24, 153–171, 1958.

Author derives more mathematical identities [see title source **4,** p. 63 ff, 1958], relating scalar correlation functions and the energy spectrum tensor in axisymmetric homogeneous turbulence. Computations of double velocity correlation coefficients behind wire gauze are given.

G. Birkhoff, USA

Aerodynamics

(See also Revs. 2345, 2356, 2362, 2365, 2368, 2369, 2371, 2372, 2379, 2380, 2381, 2382, 2384, 2403, 2406, 2442, 2447, 2467, 2477, 2534, 2592, 2611, 2623)

Book—2414. Richter, W., Aerodynamics [Flugmechanik], Leipzig, B. G. Teubner Verlagsgesellschaft, 1959, vi + 296 pp. DM 15.60.

2415. Lees, L., Hartwig, F. W., and Cohen, C. B., Use of aerodynamic lift during entry into the earth's atmosphere, *ARS J.* **29,** 9, 633–641, Sept. 1959.

Rather significant generalized results are obtained under the following two sets of simplifying assumptions: (1) A non-moving atmosphere having a density altitude defined by the usual exponential law; the aerodynamic and inertia forces dominate the motion (the combined gravity and centrifugal forces are relatively negligible); lift and drag coefficients are constant; (2) An atmosphere as in (1); a constant (g) field and only normal inertia forces during a modulated lift program. Maximum total deceleration force and avoidance of out of the atmosphere skips are the control parameters used.

It is shown that for modest application of lift $0.25 < (CL/CD) < 2$ marked reductions in peak deceleration, particularly at the larger entry angles, are available and that the high-temperature problem is about the same as for the zero-lift entry. Thus angle re-entry precision requirement is relaxed from the standpoint of peak deceleration forces. Moderate negative lifts may be necessary to avoid atmosphere skips in some instances. Numerical cases for entry speeds of 26,000 ft/sec and 35,000 ft/sec at an entry altitude of 400,000 ft are given in detail. No estimates are made of the errors resulting from the simplifying assumptions.

M. G. Scherberg, USA

2416. Kuhn, R. E., Semi-empirical procedure for estimating lift and drag characteristics of propeller-wing-flap configurations for vertical- and short-take-off-and-landing airplanes, NASA Memo 1-16-59L, 38 pp., Feb. 1959.

There exists, on the one hand, a large body of experimental investigations on the influence, at zero forward speed, of propeller slipstreams on the aerodynamic performance of wing-flap combinations suitable for VTOL and STOL airplanes. There exists, on the other hand, the still larger body of conventional wing-flap information, but there are only very few experiments on the combined effect of both slipstream deflection and forward speed on the aerodynamics of such configurations. Present paper gives an interpolation formula for estimating lift and drag for these combined effects based on experimental values in just these endpoints of power-off and speed-off conditions respectively. Investigation uses simple momentum considerations both for the deflected slipstream and for the lift-induced downwash of the pure wing. It gives total lift as the sum of power-off lift, of a direct thrust contribution caused by slipstream deflection, and of a lift augmentation term caused from the increased mass flow in the system by the higher velocity in the propeller slipstream. In order to adjust the lift values given by this resulting superposition formula to the power-off conditions, the form given to the lift augmentation term is selected by requirements of mathematical simplicity rather than by physical reasons, and to get better agreement with experiments it is further corrected by a constant factor derived from experiments. Drag is treated in an analogous manner.

To provide the reader with the necessary available experimental information, slipstream turning angle (a function primarily of flap deflection, of type of flaps used, and of the ratio of the total extended flap chord to propeller diameter) and thrust recovery factor (a function of turning angle, flap configuration, and propeller arrangement) are mapped on the basis of experiments made at zero forward speed.

Comparison of the few experimental results for the combined effect of power and speed shows reasonably good agreement to make this method applicable in the unstalled flight regime and to make it useful in preliminary design estimates of the performance of VTOL and STOL airplanes.

H. Behrbohm, Sweden

2417. Monakhov, N. M., Calculations for the re-circulation of a slipping wing of large aspect-ratio (in Russian), *Izv. Vysbch. Uchebn. Zavedenii Aviats. Tekhn.* no. 1, 19–26, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 180.

A method of calculation is evolved for a slip wing of large aspect ratio on the basis of the theory of the lifting vortex surface. The wing is assumed to be infinitely fine and plane. The

problem is solved in a linear setting. The integral equation for determining the circulation is derived with an exactness to the second order of smallness in relation to the relative chord of the wing. A method is put forward for the solution of this equation which permits the finding of approximate expressions for the determination of the distribution of the intensities of the vortex layer of the wing along and transversely to the flow. From the solutions obtained it is evident that the intensity of the vortices in the sections of the wing along the flow, excluding sections close to the tips of the wing, calculated to a precision of the second order of smallness, is propagated in conformity with the principle found in the plane-parallel flow about the profile of a parabola. Author holds the view that the principle established by him for the distribution of the intensity of vortices in sections along the flow of a slip-wing justifies the application of the method of "three-quarters of the chord" for the calculation (within the limits of the linear theory) of the aerodynamic characteristics of delta wings being flown about by an incompressible and inviscid flow. This he explains by the fact that the circulation around the profile of the parabola with a lifting vortex located at a distance from the leading edge equal to 1/4 of the chord replacing it, and the fulfilling of the boundary condition of the inability to flow past at a point distant from the nose of the profile by 3/4 of the chord (the method of "three-quarters of the chord" already referred to) is capable of exact solution. B. N. Korchagin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2418. Bulygina, E. B., On the problem of a wing of a given volume with minimum wave drag, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 6, 1180–1184, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Although the results given in this paper are attractively simple, reviewer believes them to be incorrect, since they do not contain the inherent singularity occurring in the linear theory when the wing leading edge is sonic. Mathematically, the difficulty may have arisen from author's treatment of the function describing the wing surface as twice-differentiable; in the present context this function has discontinuous slope at the wing edges. Author fails to give reference to other works on same problem, e.g., AMR **11** (1958), Rev. 1701, or compare results.

J. E. McCune, USA

2419. Beane, B. J., Calculation of optimum lift distribution for the sonic-edge diamond planform wing from spanwise moments obtained from the corresponding artificial singularity distribution, Douglas Aircr. Rep. SM-23017, 14 pp., Dec. 1957.

Author considers evaluation of the load distribution for minimu drag due to given lift over a diamond planform wing with sonic leading edges in supersonic flow. The distribution is approximated in the form $a(x) + b(x)y^3 + c(x)y^4$, x being the free-stream direction. The three coefficients are evaluated so as to give exact results for the zeroth, second, and fourth moments at each chord. These moments are obtained from a singularity distribution obtained by E. W. Graham ["The calculation of minimum supersonic drag by solution of an equivalent two-dimensional potential problem," Douglas Aircr. Co. Rep. SM-22666, Dec. 1956; AMR **10** (1957), Rev. 3392]. Results are shown to be in excellent agreement with exact solution and an approximate solution obtained by another (more laborious) method. P. Chiarulli, USA

2420. Drake, D. G., Quasi-steady derivatives for the subsonic flow past an oscillating aerofoil in a porous wind tunnel, *Aero. Quart.* **10,** 3, 211–229, Aug. 1959.

Linear theory is used to develop mathematical expressions for lift and pitching moment derivatives for a two-dimensional airfoil in a porous tunnel. It is assumed that the normal velocity at the wall is proportional to the pressure drop across it. The range of the parameters permits solutions for all porosities from a closed tunnel to an open jet, as well as for various Mach numbers and height/chord ratios. Author concludes that elimination or substantial reduction of wind-tunnel wall interference in porous wall tunnels is unlikely for quasi-steady flow. Reviewer notes possible misprint in next to last term of Eq. [67].

Alberta Alksne, USA

2421. Rogozhin, V. S., Sufficient conditions for the existence of unique solutions of inverse boundary value problems, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 6, 1141–1148, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author determines mathematically sufficient conditions for uniqueness of the geometry of an airfoil section, given the fluid velocity distribution. The particular case of a profile, smooth at the stagnation point and with a finite-angle trailing edge, is considered in some detail. Also discussed is the problem of improving the properties of a profile, subject to its length being held constant and fluid conditions at the stagnation point and trailing edge remaining unchanged, while preserving uniqueness of profile.

E. E. Jones, England

2422. Murphy, C. H., Jr., Steady-state circular pitching and yawing motion of symmetric missiles, *J. Aero/Space Sci.* **26,** 9, 600–601 (Readers' Forum), Sept. 1959.

2423. Walker, W. G., and Copp, M. R., Summary of VGH and V-G data obtained from piston-engine transport airplanes from 1947 to 1958, NASA TN D-29, 41 pp., Sept. 1959.

Vibration and Wave Motion in Fluids

(See also Revs. 2244, 2329, 2332, 2333, 2334, 2335, 2345, 2355, 2382, 2386, 2403, 2407, 2454, 2616, 2623)

2424. Moiseev, N. N., On the theory of nonlinear vibrations of a liquid of finite volume, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **22,** 5, 860–872, 1958. (Pergamon Press, 122 E. 55th St., New York, 22, N. Y.)

Paper proposes a general nonlinear theory for the description of large amplitude standing waves on the surface of a fluid in an arbitrarily shaped container. The free vibration problem is solved by expansion of the velocity potential and the surface shape in power series in ε, the amplitude of small waves, with coefficients that are both time- and space-dependent. An iteration method is used to obtain these coefficients from the nonlinear boundary conditions at the surface in terms of complete sets of functions.

Forced vibrations are analyzed for the case where the forcing is in the form of a periodic force applied at the surface. The velocity potential and the surface shape are now expanded in power series of the forcing amplitude. The procedure of solution is very involved and machine computation is recommended by the author. The convergence of the numerous series and the validity of many of the truncations and approximations is not proven and is in doubt. The author suggests that for investigation in regions close to resonance (for instance, in the theory of flutter of a wing carrying fuel tanks) it may be necessary to create a model which would take into account the possibility of wave-breaking and the increase of entropy. The author's discussion of the resonance behavior is related to a performance diagram characteristic of a hardening system. There seems to be a discrepancy since large amplitude fluid surface waves are usually characterized by performance diagrams of a softening system. M. I. Yarymovych, USA

2425. Berlot, R. R., Production of rotation in a confined liquid through translational motion of the boundaries, *ASME Trans.* 81E (*J. Appl. Mech.*), 4, 513–516, Dec. 1959.

The fluid contained in a cylindrical tank which is oscillated laterally to its axis has been found to rotate when the driven frequency is close to the natural frequency of surface vibrations. This is because any slight departure of the center of gravity of the fluid from the plane containing the axis and the driving force will, by the action of centrifugal force, be amplified until an equilibrium is reached between the action of centrifugal force and that of gravity. This would be true for a frictionless fluid, but the velocity on the axis of the vortex would then approach infinity. In a real fluid, viscosity will prevent this from happening.

The motion is analyzed and an analogy drawn with the behavior of a system of spherical pendulums. The results for a single pendulum, both by digital and analog computors, are in agreement with experimental observations of the motion in an oscillating tank.

G. H. Lean, England

2426. Clark, C. B., Speed of straight waves in a ripple tank, *Amer. J. Phys.* **27,** 7, 478–483, Oct. 1959.

Author assumes perfect incompressible fluid and irrotational flow. The problem is to determine the velocity potential of the fluid and the components of the velocity which satisfy the boundary conditions.

Author treats cases where (a) the effects of surface tension are neglected and (b) they are taken into account. The equation of continuity, the hydrodynamic equation of motion, and expressions for the acceleration, velocity and velocity potential are given. Effects of surface tension are taken into account by modifying the boundary condition of the free surface.

In a bibliographical note author refers to a publication by Dwight, the subject of which is a method of determination of surface tension.

Maria A. Kirsch, Germany

2427. Keulegan, G. H., Energy dissipation in standing waves in rectangular basins, *J. Fluid Mech.* **6,** 1, 33–50, July 1959.

Damping of standing waves of finite amplitude in various liquids in glass or lucite basins has been measured. Results have been compared with a theory calculating the dissipation due to the boundary layers at the bottom and the walls of the basin. For liquids wetting the walls this theory accounts for the major part of damping. For non-wetting liquids a large excess damping has been observed in small basins. This is attributed to surface activity.

L. J. F. Broer, Holland

2428. Sokolova, I. N., The method for causing irregular wave formation in a basin (in Russian), *Trudi Mosk. Gidrofiz. In-ta, Akad. Nauk SSSR* **11,** 36–41, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12662.

The amplitude of vertical swinging on a regular wave action obtained from the equation

$$\frac{d^2\zeta}{dt^2} + 2\mu\frac{d\zeta}{dt} + \omega_0^2\zeta = \omega_0^2 a_0 \sin \omega t$$

is compared with the experimental data. By introducing correction coefficients to take into account the body dimensions, the theoretical and experimental curves show good agreement. A measure of divergence in the experimental curves from the precalculated is explained by the nearness of the accepted principle of relationship between the resistance and the velocity. The procedure is given for obtaining irregular waves. In a concrete-lined rectangular tank waves were formed with changes of frequency following the principle

$$\nu = \nu_0 + kt,\ \nu = \nu_0 + \alpha \sin \omega t$$

Yu. P. Ivanilov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2429. Panov, N. N., Velocity of propagation of the front of a filling wave in discharges from a timber boom (in Russian), *Sb. Nauchn. Tr. Tsentr. N.-i. In-ta Lesoplava* no. 2, 77–84, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12611.

A formula is proposed for the determination of the velocity C_+ of the front of a filling wave in the "lower water" of timber dams (booms)

$$C_+ = \nu_0 + \sqrt{\frac{1}{2} g (h_1 + h_0)\mu^2}$$

where ν_0 and h_0 are the velocity of the flow and the depth in the water lower than the dam up to the beginning of the discharge (channel), h_1 is the depth at the same spot with a steady flow as the result of a prolonged discharge with a constant output, μ being an empirical coefficient. Using a rectangular laboratory trough and with a practically instantaneous alteration of the discharge the author obtained a formula (the result of specially carried out experiments) expressing the coefficient μ in relation to h_1/h_0 with one parameter which appears to indicate the degree of roughness of the river bed. For actual river beds where the relation for a coefficient of a similar nature appears to consist of many parameters, the author proposes to carry out special experiments, which should make it possible to apply corrections to the first formula for the coefficient μ.

V. A. Arkhangel'skii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2430. Rogozhin, V. S., The reverse problem in the theory of impact (in Russian), *Uch. Zap. Kazansk. In-ta* **117,** 2, 36–37, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 331.

The liquid is ideal and incompressible. The problem is a plane one. The free surface is horizontal. The floating contour, the shape of which was previously unknown, suddenly acquires a vertical velocity. The problem is solved by means of the reflection of region z, occupied by the flow, onto the lower semispace of the variable ζ. The function $z(\zeta)$ is found with the aid of the Keldysh-Sedov formula with the added condition that the relation $\psi(\zeta)$ on the contour is known. The examples given by the author are known.

M. I. Gurevich

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2431. Erokhina, N. I., The influence of viscosity on wave resistance (in Russian), *Trudi Dalnevost. Politekhn. In-ta* **46,** 2, 1–7, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 366.

Generally when making calculations for wave resistance no account is taken of the viscosity of the liquid. In consequence the found experimental values for resistance frequently diverge from the theoretical calculations. The effect of viscosity is seen in the formation at the surface of the moving vessel of a boundary layer which at the bows has a thickness of the order of the beam of the ship. The influence of viscosity can be computed by increasing, when making the calculations, the transverse dimensions to the so-called thickness of displacement, which is linked with the breaking up of the liquid in the boundary layer when the body is flown about by the current. For the purpose of calculating wave resistance it is necessary to determine the ordinates of the wave profiles at various points of the body's surface. The author makes this computation when considering and without considering the thickness of displacement, using the method of the function of influence (N. N. Kabachinskii's method). The results are compared with the experimental data. Basically, taking account of the thickness of displacement improves the results, but in a number of cases the correction for viscosity only widens the divergence with the experiment. The author maintains that in order to evaluate the

influence of viscosity in full the use of only one thickness of displacement is inadequate. V. S. Voitsenya

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2432. Benjamin, T. B., Shearing flow over a wavy boundary, *J. Fluid Mech.* **6,** 2, 161–205, Aug. 1959.

Author calculates components of stress on a rigid, flexible or mobile wavy boundary, due to two-dimensional stable laminar flow. Linearized theory is employed assuming a small amplitude-wavelength ratio for boundary profile, and a Reynolds number large enough for viscous effects to be confined within thin "friction layers," but not so large as to bring about separation on the leeward side of the waves.

Complexity of calculation depends on depth to which perturbations due to boundary penetrate the primary parallel flow and the existence under stated conditions of critical points in the flow. Particular attention is given to a linear velocity profile and an approximation to a laminar boundary layer. Validity of solutions for laminar and turbulent boundary layers is carefully examined. It is suggested that analysis may also apply to turbulent flows where mean-velocity profile replaces laminar profile, both for fluid-solid interfaces and fluid-fluid interfaces with large viscosity and density ratios.

Particularly significant is the occurrence of minima in both stress components on the leeward slopes of waves, recalling the sheltering theories of wave generation. Only the experiments of Motzfeld are found compatible with conditions of problem, and satisfactory agreement is found. Fourier's theorem enables results to be extended to more general boundaries, stress distributions being calculated for uniform shear flow over a single hump.

Reviewer considers this a substantial contribution to work on wave generation. J. N. Hunt, England

2433. Zoryan, Z. A., The physical modeling of a water hammer (in Russian), Intercollegiate conference on the application of physical modelling to electrotechnical problems and mathematical modelling (Mezhvuz. Konferentsiya po Primeneniyu Fiz. Modelirovaneya v Elektrotekhn. Zadachakh. i Matem. Modelirovaniya), Moscow, 1957, 55–56; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 427.

The theses contained in the report of the conference were:

(1) The conditions of similarity in the phenomenon of water hammer, established by I. V. Egiazorov;

(2) Recommendations to control the magnitude of the velocity of the propagation of water-hammer waves on a model by means of an air-inflated hose inserted in the pipe conduit;

(3) The formula for determination of the velocity of the water-hammer wave in case 2. N. A. Kartvelishvili

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2434. Stepanov, P. M., On the submerged jump of water (in Russian), *Gidrotekhn. i. Melioratsiya* no. 1, 43–53, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 439.

Results are expounded of the experimental investigation of the phenomenon of the submerged jump in a rectangular prismatic (river) bed with a horizontal bottom. The investigations were carried out for the case of a flow of water from below a shield and for the case of an overflow of water over a spillway of practical profile. Froude number, referred to the compressed section, changed in the limits of 5 to 50. The degree of submergence $\xi = h_1/h_2$ changed from 1 to 2.4; here h_1 is the depth of the lower water, h_2 is the depth coupled with the compressed. Experimental relations are recommended for the determination of the length of the submerged jump of water and for the derivation of curves for the free surface and the delineation of the transit stream.

T. N. Astaficheva

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Fluid Machinery

(See also Revs. 2242, 2324, 2326, 2343, 2347, 2348, 2349, 2416, 2466, 2551, 2552)

2435. Alef, W., Numerical calculation of induced velocities on propeller blades (in German), *Schiffstechnik* **6,** 30, 42–48, Feb. 1959.

Paper is devoted to the computation of velocities which are induced on the surface of the propeller blades by the free vortices. This task is simplified as follows: (a) It is assumed that the induced velocity has no radial component, so that only the axial and tangential components of the induced velocity must be computed. (b) The computation is referred to a number of points which are situated on the radially directed straight line from where the free vortices emerge. Each propeller blade is substituted by a lifting straight line. Thus it is assumed that the velocities induced by the free vortices have the same values at all points of the same cylindrical section of the blade.

As is generally known, the simplification as outlined in (a) and (b) for the computation of screw propellers that are moderately loaded does not involve any major errors. The method of computation is illustrated by two numerical examples.

M. Strscheletsky, Germany

2436. Sawada, T., The drag of lattice of many parallel circular cylinders at low Reynolds number, *J. Phys. Soc. Japan* **14,** 6, 837–842, June 1959.

The relations between the drag coefficient C of lattice of many parallel circular cylinders and Reynolds number R were studied experimentally. The drag of the specimen falling in a tower was measured in the region of R = ca 0.25 ~ 1.0. If C vs R curve of a cylinder by Wieselsberger is used as standard, C vs R relations of lattice are approximately the same as Wieselsberger's, when b/d = 250 and 125, with d being the diameter of the cylinder, and b the distance of the centers of the two cylinders. Accordingly it is seen that Imai's formula on the basis of the combination of Stokes's and Oseen's approximations is better than Tomotika and Aoi's formula on the basis of Oseen's. The C vs R relations of lattice when b/d = 50, 25 and 12.5 are somewhat similar to Fujikawa's C vs R curves of two parallel cylinders.

From author's summary

2437. Ginevskii, A. S., Influence of the viscosity of a liquid on the extent of the circulation round the profile of a hydrodynamic lattice (in Russian), Industrial aerodynamics no. 9, Moscow, Oborongiz, 1957, 5–15; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12695.

The relation is investigated of the basic geometrical parameters of a plane grid to $k_\Gamma = \Gamma/\Gamma_{ideal}$ for the circulation round the profile of the grid in a flow of viscous incompressible liquid to the circulation in a corresponding flow of ideal liquid. It is assumed that the profiles differ only slightly from straight cuttings. Equality to zero of the total vorticity of the flow beyond the grid results in the equality of velocities on the outer boundaries of the boundary layer, coinciding with the profile. Applying these conditions in the flow of ideal liquid through a grid of plates the author arrives at (with an accuracy up to the terms of the order of δ^2)

$$k_\Gamma = 1 - k\sqrt{\delta_B \delta_H}$$

where k is a function of the denseness and tolerance of the grid, while δ_B and δ_H are dimensionless thicknesses of the boundary layer, taking off from the upper and lower sides of the profile. The calculation values of k_Γ tend to reach unitary value with increase of density and decrease of the angle of tolerance. Experimental data for compressor grids, made from solid profiles, with no impact

on entry correspond to $k_T = 0.86$–0.93. The results of the experiments are basically of a qualitative character.

L. G. Naumova

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2438. Schwanecke, H., Contribution to the theory of unstationary flow in cascades of aerofoils (in German) *Schiffstechnik* **5,** 27, 97–114, June 1958.

2439. Vallander, S. V., On the application of the method of singularities to the calculation of fluid flow in radial-axial turbines, *Soviet Phys.-Doklady* **3,** 6, 1113–1116, June 1959. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **123,** 3, 413–416, Nov. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

The paper is based on the author's previous work "Fluid flow in turbines," [*Dokladi Akad. Nauk SSSR* **84,** no. 4, 1952; AMR **5** (1952), Rev. 3205], in which the solution of a three-dimensional flow by the introduction of orthogonal curvilinear coordinates is transferred to the solution of a two-dimensional problem. In this paper the author shows that in these cases it is possible to use the method of singularities and he presents expressions for the flow produced by a lattice of sources and a lattice of vortices based on the Dirac delta-function and the periodic Dirac delta-function.

J. Polasek, Czechoslovakia

2440. Baumgartner, F., and Amsler, R., Presentation of a blade-design method for axial-flow turbines, including design and test results of a typical axial-flow stage, ASME Gas Turb. Power Conf., Cincinnati, Ohio, Mar. 1959. Pap. 59-GTP-4, 8 pp.

2441. Lang, R., and Petrick, E. N., Application of electrical analog theory in the preliminary design of air-cooled turbines, ASME Gas Turbine Power Conf., Cincinnati, Ohio, Mar. 1959. Pap. 59-GTP-15, 8 pp.

2442. Yeh, H., An actuator disc analysis of inlet distortion and rotating stall in axial flow turbomachines, *J. Aero/Space Sci.* **26,** 11, 739–753, Nov. 1959.

Flow behind rotor (or stator) blade row due to arbitrary inlet distortion along both circumferential and spanwise directions is treated using classical actuator disk approximation. In general, it is shown that spanwise and circumferential distortion waves interact so that combined influence is not sum of influences of the two simple types of distortion.

Examples given show influence of various design parameters. Role played by cascade characteristics is illustrated. Analysis shows there can be two types of self-induced distortion—a purely spanwise, axisymmetric type and a travelling, circumferential plus spanwise type. It is indicated that a purely circumferential type travelling stall should precede these.

From author's summary by R. A. A. Bryant, Australia

2443. Meyer, R. F., An experimental study of rotating stall in a two-stage axial compressor, Nat. Res. Counc., Canada, LR-259, 54 pp., Aug. 1959.

The stalling behavior of an Orenda CT-100, experimental two-stage axial compressor was studied at the constant operating speed of 3000 rpm. Rotating stall was observed to commence at a mass flow coefficient of 0.435 and as the mass flow was reduced several different patterns of rotating stall were observed. In two ranges of operation, "steady" patterns consisting of three rotating stalls were observed; in two other ranges of operation rotating stall was observed but the stall patterns were continually changing, while for very low mass flow operation the flow over the whole of the annulus appeared to be stalled. Reversed flow within the stalls was found to be an important feature of rotating stall.

From author's summary

2444. Evans, W. T., and Mort, K. W., Analysis of computed flow parameters for a set of sudden stalls in low-speed two-dimensional flow, NASA TN D-85, 24 pp., Aug. 1959.

An analysis is presented from which it is inferred that there are two distinct mechanisms of nose stall, presumed to be "bubble-bursting" and "reseparation," as described in the existing literature. For a set of airfoil stalls attributed to the latter mechanism on the basis of a criterion proposed by Tani and Owen independently, a correlation is demonstrated between high theoretical velocity peaks at stall and either steep initial adverse gradients or thin boundary layers in the region of these gradients. The correlation does not apply to stalls specifically attributed to bubble-bursting.

From authors' summary

2445. McCloud, J. L., III, and McCullough, G. B., Comparison of calculated and measured stall boundaries of a helicopter rotor at advance ratios from 0.3 to 0.4, NASA TN D-73, 28 pp., Sept. 1959.

Computations were made of the performance characteristics of a helicopter rotor by the method of NACA TN 3747. The computed characteristics are compared with the measured characteristics of a geometrically similar rotor reported in NACA TN 4367. The calculated and measured stall boundaries based on rotor torque indications were roughly parallel, but the calculated boundary represented rotor lift coefficients which were lower than the experimental values.

In operational regions free of calculated blade stall, the agreement between calculated and measured values of rotor thrust or lift was good. The computed propulsive force was greater than the measured force; whereas the opposite was true of the torque. The absence of hub drag and windage terms in the calculations could account for part of these discrepancies.

From authors' summary

2446. Jewel, J. W., Jr., and Heyson, H. H., Charts of the induced velocities near a lifting rotor, NASA Memo 4-15-59L, 63 pp., May 1959.

This paper is a compilation of induced-velocity charts for both uniform and nonuniform loading. These charts should be applicable to several aerodynamic interference problems involving rotary-wing aircraft.

From authors' summary

2447. Ando, T., A study on Voith-Schneider propeller, *Bull. JSME* **2,** 5, 23–29, Feb. 1959.

Author studies the flow around Voith-Schneider propeller under the following assumptions: propeller blades rotate clockwise with constant angular velocity; the incompressible medium flows with a uniform velocity. The force and moments acting on a blade are obtained by use of Kutta's condition. The treatment is quasi-steady, the vortices are disregarded, the chord length is small. Three fundamental coefficients appear in the analysis of the dynamics of the system: mean thrust, mean side force and mean power coefficients. The calculation of these quantities involves the use of elliptic functions and is complicated. Numerical example refers to the relative chord length $c/R = 0.2$ (R = tip radius). The results are presented in form of graphs: first and second derivatives of the fundamental coefficients as functions of the parameters of the system. Author justifies the omission of the effects of the vortices on the performance of the propeller by stating that this is quantitatively given as the square of the solidity, whereas the more important influence of the curvature of blade path is estimated as large as the product of the chord length and the solidity. The latter is assumed to be small. Author intends to get some fundamental concepts of aerodynamical action of rotor blades of a cyclogyro aircraft.

Comment of the reviewer: Compressor theory shows that the problem of disregarding effect of vortices is an open one in the case of small aspect ratio.

M. Z. v. Krzywoblocki, USA

2448. O'Bryan, T. C., and Hammack, J. B., Flight performance of a transonic turbine-driven propeller designed for minimum noise, NASA Memo 4-19-59L, 22 pp., May 1959.

Paper describes a flight investigation of the performance of an advance-ratio-4.0 propeller designed for a Mach number of 0.82 showed an efficiency of 68%. A comparable propeller designed for optimum advance ratio (≈ 3) would have an efficiency as much as 15% higher. From authors' summary

2449. Bachmann, R. W., Clutch-fluid coupling-hydraulic torque converter..... application considerations and performance comparisons, ASME Design Engng. Conf., Philadelphia, Pa., May 1959. Pap. 59-MD-6, 8 pp.

Flow and Flight Test Techniques and Measurements

(See also Revs. 2351, 2352, 2364, 2367, 2372, 2400, 2407, 2420, 2447, 2464, 2511, 2520, 2592, 2598, 2640)

2450. Spencer, N. W., Boggess, R. L., LaGow, H. E., and Horowitz, R., On the use of ionization gage devices at very high altitude, *ARS J.* **29,** 4, 290-294, Apr. 1959.

Based on assumptions regarding kinetic properties of the constituent particles in the upper atmosphere, the applicability of the thermionic ionization gage in measuring gas properties from an orbiting satellite is developed.

Partial pressures inside the ionization chamber are related to external pressures as a function of temperature and relative velocity of the gas. The latter depends upon orientation of the chamber orifice and the molecular velocity. A scanning technique about an axis normal to the orbit is suggested for determining relative contribution of the heavier and lighter molecules. If the temperature is known, pressure and density may be obtained. By addition of a spectrometer-type instrument to the chamber it appears that composition, concentrations, and velocity distribution functions may also be investigated.

A discussion of measuring problems with thermionic, omegatron, radioactive, cold cathode, and spectrometer-type gages is included. H. M. Spivack, USA

2451. Maizel', M. B., Multirange differential manometer, *Measurement Techniques* no. 1, 40-41, Aug. 1959. (Translation of *Izmeritel'naia Tekhnika, USSR* no. 1, 35-36, Jan./Feb. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2452. Evans, J. C., Pneumatic gauging techniques, *Research, Lond.* **11,** 3, 90-97, Mar. 1958.

An account is given of the pneumatic gaging technique both in its theoretical and practical aspects. An empirical approach establishes a set of simple, linear equations which can be used for design purposes; they are applied to a particular problem of measurement by way of illustration. Examples of applications of the technique to a variety of problems are cited. The simplicity and power of the technique recommend it when accurate measurements must be made of dimensional size or of displacement in slowly moving systems. From author's summary

2453. Barraclough, T. W., Collier, R. D., and Summers, A. C., Dynamic force measuring system for machinery vibration with particular application to balancing of assembled machines, *J. Acoust. Soc. Amer.* **31,** 8, 1104-1107, Aug. 1959.

The dynamic force measuring system for the measurement of machinery vibration is based on the use of four piezoelectric force transducers. These transducers are installed between the feet of the machine under test and a terminating foundation, preferably a large seismic mass. The four signals are combined in two ways: (1) as a phasor sum to provide a single vertical force measurement and (2) as a sum and difference with equivalent moment arms to provide torque measurements. These fundamental measurements are based on force and torque equations developed from the six motions of an assumed rigid body. At the fundamental frequency of machinery vibration the two combined signals provide a measure of static and dynamic unbalance. The force spectrum may be analyzed by conventional means to provide frequency and amplitude information. From authors' summary

2454. Perkins, F. E., and Eagleson, P. S., The development of a total head tube for high frequency pressure fluctuations in water, Mass. Inst. Technol., Hydrodynamics Lab., Dept. Civil & Sanitary Engng. TN 5, 46 pp., July 1959.

This technical note describes the design, construction, analysis and initial use of a total head tube for the measurement of instantaneous pressure fluctuations in a fluid.

The primary distinguishing feature of this gage is that although the tube is only 1/8-in. o.d. stainless steel, the pressure transducer—a cylindrical barium titanate ceramic—is located within the tube and directly at the tip where the pressure fluctuations occur. The elimination of a fluid coupling between the tip and transducer enables attaining a very high natural frequency, estimated to be about 80,000 cps in water. The sensitivity of the gage was measured as 5.76 milli-volts per psi of applied pressure. The gage does not respond to static pressures and its response is attenuated at frequencies below 8 cps; however, measurements down to at least 5 cps are possible with no more than a 5% loss in sensitivity.

The general characteristics of ceramic transducers and methods of ceramic transducer design are presented in a manner that should make their use and possibilities more generally understood.

The results of some measurements of turbulent intensities and energy spectra in the wake behind a circular cylinder are briefly presented. From authors' summary

2455. Koenig, D. G., Greif, R. K., and Kelly, M. W., Full-scale wind-tunnel investigation of the longitudinal characteristics of a tilting-rotor convertiplane, NASA TN D-35, 39 pp., Dec. 1959.

Tests of a tilting-rotor convertiplane, currently designated the XV-3, were made to investigate both mechanical and aerodynamic aspects of this type of aircraft. Only the longitudinal aerodynamic characteristics are the subject of this report.

Aircraft configuration variables were angle of attack, rotor-pylon angle, power, and longitudinal control. With the exceptions of a few runs at or near zero airspeed, and several propulsive efficiency runs at airspeeds up to 155 knots, most of the tests were made between approximately 60 and 120 knots. The tests at a given airspeed and pylon angle usually consisted in varying one of the aircraft variables with the others held constant. For each pylon angle setting, trim control and power settings simulating level flight of 4700 pounds gross weight were experimentally determined for at least one airspeed.

The XV-3 rotor was found to perform well aerodynamically, both as a helicopter rotor and as a propeller for the present XV-3 configuration. Although reducing rotor speed might increase somewhat the operating propulsive efficiency of the XV-3, large rotor flapping angles resulting at low rotor speeds will probably serve as a lower limit to rotor speed. The XV-3 was found longitudinally stable with the moment center near the pivot line of the pylon for pylon angles between about 10° and 90° at airspeeds above 60 knots. Several steady-state conversion processes were defined and the choice of any one does not seem to depend on the speed-power requirements.

From authors' summary

2456. McKinney, M. O., Jr., Low-speed wind-tunnel investigation of a wingless jet VTOL transport model, NASA TN D-57, 77 pp., Oct. 1959.

A wind-tunnel investigation has been made of the static stability and lift and drag characteristics of a small-scale model which represented a wingless turbojet-powered vertical-take-off-and-landing (VTOL) transport airplane, which might have some performance advantage over a winged airplane for cruise at high subsonic speeds at very low altitudes. The model consisted of a fuselage with conventional tail surfaces at the rear and with 12 simulated jet engines near the center which could be tilted from a horizontal attitude for normal forward flight to a vertical attitude for hovering flight. The investigation consisted of power-off and power-on longitudinal stability and lift and drag tests and power-off lateral stability tests. The results of the investigation showed that satisfactory static longitudinal stability characteristics could be obtained and that a maximum trimmed lift-drag ratio of about 5 could be obtained at a lift coefficient of about 0.15, which is approximately the lift coefficient for a Mach number of 0.6 at sea level for a full-scale airplane of the type represented by the model.

From author's summary

2457. Hickey, D. H., and Ellis, D. R., Wind-tunnel tests of a semispan wing with a fan rotating in the plane of the wing, NASA TN D-88, 44 pp., Oct. 1959.

An investigation was conducted to determine the aerodynamic characteristics of an aspect-ratio-4 semispan wing model with a fan rotating in the plane of the wing. The effects of a ground plane, fan duct inlet and exit vanes, and a wing leading edge with increased camber and radius were obtained.

Three-component forces, air flow through the fan, wing static pressures, and power input to the electric motor, were measured. These data cover tip-speed ratios from 0 to 0.5.

The data indicate ground effect causes a significant loss in lift, duct inlet vanes improve aerodynamic characteristics and flow through the propeller disk, and duct exit vanes can be used to redirect the propeller flow for propulsion.

From authors' summary

2458. Weiberg, J. A., and Page, V. R., Large-scale wind-tunnel tests of an airplane model with an unswept, aspect-ratio-10 wing, four propellers, and blowing flaps, NASA TN D-25, 39 pp., Sept. 1959.

The longitudinal aerodynamic characteristics were determined and compared with data previously presented for the model with two propellers. The lift increment due to thrust was proportional to the slip-stream velocity and, for a given thrust coefficient, was proportional to the wing area in the slipstream. The drag for a given thrust coefficient and the momentum coefficient required for attached flow were relatively unaffected by the number of propellers. The downwash variation with angle of attack for both the four- and two-propeller models increased with thrust coefficient approximately in proportion to the increase in lift-curve slope.

From authors' summary

2459. Maki, R. L., and Giulianetti, D. J., Low-speed wind-tunnel investigation of blowing boundary-layer control on leading- and trailing-edge flaps of a full-scale, low-aspect-ratio, 42° swept-wing airplane configuration, NASA TN D-16, 29 pp., Aug. 1959.

Single- and double-droop leading-edge flaps and trailing-edge flaps with blowing BLC were tested for an angle-of-attack range through stall. Lift, drag, pitching-moment, and rolling-moment data were recorded for leading-edge flap deflections to 60° and trailing-edge flap deflections of 40° and 55°. Effects of plugs in the trailing-edge nozzle on lift and roll control with flaps differentially deflected as ailerons are presented. From authors' summary

2460. Wattson, R. K., Jr., and Hoehne, V. O., Wind-tunnel tests of shrouded propellers and their application, *Aero/Space Engng.* **18,** 7, 58-62, July 1959.

The best application of the shrouded propeller as a propulsive unit is one in which advantage is taken of the normal forces that the shroud can provide at low and moderate angles of attack. These normal forces can be used for lift or for control.

From authors' summary

2461. Marsden, D. J., A small wind tunnel for investigating the characteristics of a wing in a finite jet, including results of a model with a suction flap, Nat. Res. Counc., Canada Lab. Rep. see 2407 LR-255, 46 pp., May 1959.

An open return blower tunnel producing a 0.667-ft diameter free jet is described. This jet is considered to be a simplified model of a fully contracted propeller slipstream which can be used to investigate the interactions of propeller slipstreams and wings with flaps.

Measurements were made using a wing-flap model having a 30 per cent chord flap with suction boundary-layer control. Results obtained with this facility were comparable with results of other similar investigations made with wing-flap models operating in a propeller slipstream.

Some of the ways in which the airflow over a high lift wing in a finite jet differs from that over the same wing in an infinite stream are illustrated. From author's summary

2462. Pearson, A. O., Wind-tunnel investigation at Mach numbers from 0.40 to 1.14 of the static aerodynamic characteristics of a nonlifting vehicle suitable for reentry, NASA Memo 4-13-59L, 14 pp., May 1959.

The investigation was conducted in the Langley 8-ft transonic pressure tunnel on a vehicle designed to use a heat sink and blunt shape to alleviate the effects of heating encountered during reentry of the earth's atmosphere. The effects of modifying the intersection of the face of the model with the afterbody from a sharp corner to a rounded edge were also investigated. Tests were conducted at angles of attack from approximately $-3°$ to $20°$, and the Reynolds number varied from about 2.0×10^6 to 3.6×10^6.

From author's summary

2463. van der Bliek, J. A., Notes on half model testing in wind tunnels, Nat. Aero. Establ., Canada, Lab. Rep. LR-235, 31 pp., Jan. 1959.

A short review is given of the effects associated with half-model technique in wind-tunnel testing. These include tunnel-wall boundary layer and gap between model and tunnel wall. Reflection plane configurations are considered. Some experimental data on comparison between full and half-model tests are given.

From author's summary by E. A. Brun, France

2464. Miki, T., Hasegawa, Y., and Iai, S., On the aerodynamic problems of the high speed train, *Bull. JSME* **2,** 6, 355-364, May 1959.

Paper gives results of measurements in wind tunnel, using 1/10 and 1/40 scale models. Streamlining of front gives considerable reduction of drag, especially for short trains. Drag is also reduced by covering gaps between cars with flush diaphragms; this is particularly important for long trains. Effects of side winds are considered.

Results are of great interest to engineers concerned with high-speed trains, but not of much general research interest.

W. A. Mair, England

2465. Holder, D. W., and Cash, R. F., Experiments with a two-dimensional aerofoil designed to be free from turbulent boundary-layer separation at small angles of incidence for all Mach numbers, *Aero. Res. Counc. Lond. Rep. Mem.* 3100, 50 pp., 1959.

2466. Aerodynamic characteristics in the approach, superfine and negative pitch ranges of two four-bladed propellers with NACA series 16 blade sections; a report of tests carried out jointly by the technical staffs of de Havilland Propellers, Limited, and Rotol, Limited, *Aero. Res. Counc. Lond. Rep. Mem.* 3105, 23 pp., 1959.

2467. van der Bliek, J. A., Drag measurements on AGARD model "A" in the N. A. E. 30- × 16-inch wind tunnel and comparison with other data, Nat. Aero. Establ., Canada, Lab. Rep. LR-233, 14 pp., Nov. 1958.

Results are presented of investigations on zero-lift drag of a parabolic body of revolution (called AGARD standard model "A"), carried out in the 30 × 16-inch intermittent wind tunnel for Mach numbers 0.4 to 2.0 and Reynolds numbers 2.5 to 4.8 times 10^6.

The aim of the investigation was to provide a basis for comparing wind-tunnel facilities by testing a standard model. An attempt is also made to correlate usually used cone transition Reynolds number with drag measurements on AGARD model "A".

Obtained drag data are compared with a compilation of other experimental data, as well as with some theoretical results obtained from the linearized theory. The effect of thickness of boundary layer is also evaluated. E. A. Brun, France

2468. Newsom, W. A., Jr., Wind-tunnel investigation of the aerodynamic characteristics of a model representative of a supersonic fighter-class airplane with an external-flow jet-augmented flap in low-speed flight, NASA TN D-50, 84 pp., Sept. 1959.

The model used in the investigation had an unswept wing of aspect ratio 3.0 equipped with a full-span double slotted flap. An engine nacelle was strut-mounted beneath each wing with the jet diverted upward and outward toward the slot of the double slotted flap. Compressed air was used to represent the exhaust of these pod-mounted engines. The investigation was made for three different wing positions and two different horizontal-tail positions for each wing position and included measurements of both longitudinal and lateral stability characteristics.

From author's summary

2469. Carlson, H. W., A wind-tunnel investigation of some aspects of the supersonic boom, *Aero/Space Engng.* **18,** 7, 38-39, 52, July 1959.

The far-field conditions are dependent to a large degree on the normal area distribution; they are also sensitive to model attitude for bodies that depart greatly from axial symmetry.

From author's summary

2470. Nagamatsu, H. T., Geiger, R. E., and Sheer, R. E., Jr., Hypersonic shock tunnel, *ARS J.* **29,** 5, 332-340, May 1959.

A hypersonic shock tunnel has been developed for obtaining fluid mechanic information at the high Mach numbers and corresponding stagnation temperatures encountered in flight by long-range ballistic vehicles and satellites. This report describes the hypersonic shock tunnel and presents some of the results obtained in the driven tube and in the nozzle. A stoichiometric mixture of oxygen and hydrogen with an excess of helium is ignited in the driver to produce strong shock waves in air. A shock velocity in air as high as 55,000 fps with a calculated equilibrium temperature of 16,000 K has been produced in the driven tube. The effects of high stagnation temperatures upon the detached shock wave and the pressure distribution for blunt bodies have been observed in the nozzle test section. The detachment distance decreased greatly at high temperatures. The pressure distribution for the hemisphere was found to be less than that predicted by the modified Newtonian theory. Shock-wave boundary-layer interaction at the leading edge of a flat plate was observed, and the results agreed with the analytical prediction. A detached shock wave was observed for a blunt two-dimensional body at very low densities in the test section with a flow Mach number of 19.6.

From authors' summary

2471. Jones, J. J., Shock-tube heat-transfer measurements on inner surface of a cylinder (simulating a flat plate) for stagnation-temperature range 4,100° to 8,300° R, NASA TN D-54, 18 pp., Sept. 1959.

A shock-tube investigation has been made of the heat-transfer rate to the inner surface of a hollow cylinder. The Reynolds number range was from approximately 2×10^5 to 2×10^7. The Mach number range was from about 1.8 to 2.4. The stagnation-temperature range was from 4,100° to 8,300° R.

The turbulent results could be correlated with a curve similar in form to the classical incompressible relation, except that the heat-transfer parameter was based on enthalpy rather than temperature.

Very few laminar-boundary-layer data were obtained. Boundary-layer transition occurred at a Reynolds number of about 5×10^5.

From author's summary

2472. Benson, R. S., and Woods, W. A., Measurement of travelling shock waves and transient velocities with a Farnboro indicator, *J. Roy. Aero. Soc.* **63,** 581, 317-319 (Tech. Notes), May 1959.

Paper describes a test to ascertain if the assumption of quasi-steady flow at the outlet of a two-stroke cycle engine exhaust pipe fitted with a nozzle was satisfactory. Essentially paper covers the use of a Farnboro indicator for measuring rapid pressure changes in a cyclic process by means of a diaphragm pickup, and shows the setup used. Paper is very brief and probably only of interest value and has little informative value.

A. F. W. Langford, Australia

2473. Ovsyannikov, B. V., and Kudrin, O. I., An exhaust jet outlet for a piston (motor) engine with an air connection (in Russian), *Trudi Mosk. Aviats. In-ta* no. 97, 181-190, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 270.

Paper describes the apparatus for measuring the draft of jet outlets (exhausts). The possibility is investigated of improving the draft by using ejection nozzles. The fact was established that the fitting of an ejection nozzle at the outlet of a jet exhaust outlet of a piston airplane engine can increase the draft of a jet exhaust (in situ) by 50-70%. The maximum benefit is reaped by fitting ejectors separately to each exhaust outlet. The utilization of the kinetic energy of the exhaust gases of piston engines for water jet nozzles may be of interest in the problem of improving the economic rating of ships' motors. V. L. Ivanov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2474. Howell, R. R., Experimental operating performance of a single-stage annular air ejector, NASA TN D-23, 35 pp., Oct. 1959.

The operating characteristics of a single-stage annular air ejector were established experimentally for a range of pressures and weight flows which allow the ejector to be used as a pump on the discharge end of a hypersonic blowdown wind tunnel. Limited data on the starting characteristics of open and closed hypersonic test sections are presented. Some effects of bluff-body size on the flow in an open hypersonic test section are presented.

From author's summary

2475. Kaplunov, M. P., Apparatus for the testing of ejector models (in Russian), *Trudi Rostovsk. In-ta Inzh.-d. Transp.* no. 21, 251-266, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 269.

A description is given of the apparatus used for the investigation of ejection processes taking place in the conical exhaust device on locomotives and also in the ventilation units in some types of diesel locomotive engines. Steam was used as the ejecting gas; this had a maximum pressure of 0.5 at u and a temperature of 125°–135°. The gas being ejected represented the products of combustion of petroleum (heavy oil) in a special furnace. A short description is given of the apparatus; details of the procedure employed in the experiments are furnished and also of the analysis of the data obtained. Yu. A. Lashkov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2476. Onishchenko, V. I., Mixed problem in the theory of a potential for a space with a plane round orifice (in Ukrainian), *Dop. Akad. Nauk URSR* no. 1, 21–28, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 691.

The mixed axially symmetrical problem in the theory of the potential for two harmonic functions in a space with a circular division boundary of the border conditions is reduced to the plane problem in the theory of a potential for two functions with a boundary division of the border conditions in the form of a cutting from a straight line. This, in turn, is reduced to the problem of linear conjugation. V. K. Prokopov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2477. Kurbjun, M. C., and Vogeley, A. W., Measurements of free-space oscillating pressures near propellers at flight Mach numbers to 0.72, NACA Rep. 1377, 9 pp., 1958.

Limited measurements have been made of the free-space oscillatory pressures near the tips of propellers at flight Mach numbers up to 0.72. Measurements were made at a single radial station and at three axial positions (ahead of, in the plane of, and behind the propeller disk). Comparisons, showing the effects of blade plan form and the effects of forward Mach number on oscillating pressures, are made with the theory of Garrick and Watkins.

From authors' summary

Thermodynamics

(See also Revs. 2170, 2171, 2390, 2502, 2504, 2523, 2528, 2558)

Book—2478. Wilk, S., Technical thermodynamics [Termodynamika techniczna], Warszawa, Panstwowe Wydawnictwa Techniczne, 1957, 253 pp. + charts. zl. 21. (Paperbound)

Book presents a very elementary treatment of the applications of thermodynamics and is designed as a text for technical high schools. While the fundamentals of thermodynamics are discussed very briefly, the analysis of fundamental processes and cycles is quite thorough. Of interest is the development of the subject matter without recourse to calculus at any point. Elementary combustion and heat-transfer calculations are described.

J. R. Moszynski, USA

Book—2479. Flugge, S., editor, Encyclopedia of Physics, Vol. XII: Thermodynamics of gases [Handbuch der Physik, Band XII: Thermodynamik der Gase], Berlin, Springer-Verlag, 1958, vi + 686 pp. DM 123.20 Subscription price; DM 154, single volume price.

Roughly one third of the text deals with thermodynamics and statistical mechanics, one third with kinetic theory and transport properties, and one third with vacuum techniques.

J. S. Rowlinson gives equations for the thermodynamic properties of perfect and real gases and gas mixtures, and discusses the evaluation of the definite integrals by means of several equations of state. Experimental methods for measuring the volumetric behavior of fluids are presented. The principle of corresponding states, theories of critical phases, and chemical equilibrium in mixtures of real gases are considered.

After an introduction to partition functions of various ensembles, J. E. Mayer derives equations for the translational, rotational and vibrational contributions to the thermodynamic properties of a perfect gas. The effects of symmetry number, nuclear spin, isotopes, and gas imperfections are discussed. The properties of classical and quantum gases are treated at length.

H. Grad in a section on the principles of the kinetic theory of gases gives a mathematical discussion of the foundations of the Boltzmann equation and of its normal and general solutions.

In an interesting and informative section on transport properties of gases at intermediate pressures, W. Waldmann discusses the phenomenological equations, experimental methods, the kinetic theory derivations of equations for transport properties of monatomic and polyatomic gases, and in some instances comparison of the theoretical results with experiment.

R. Jaeckel writes on the production and measurement of low pressures, and D. Alpert extends this discussion to ultrahigh vacuums, defined as the region below 10^{-4} mm of mercury.

The chapters by Waldmann and Jaeckel are in German, all others are in English. There are German-English and English-German indexes.

The excellent printing of the earlier volumes in this series is maintained. In a somewhat casual reading the only typographical error noted was in line 3 of page 73.

The reviewer feels that the first three sections of the book are addressed to experts in the field; the last three sections are more down to earth. J. A. Beattie, USA

2480. Gleyzal, A., On the determination of certain thermodynamic and physical quantities, *Quart. Appl. Math.* **17**, 3, 318–320 (Notes), Oct. 1959.

For a function $z = z(x, y)$, with $F = \partial z/\partial x$ and $G = \partial z/\partial y$, it is shown that on a $G - y$ chart the rectangular area between the lines $F = F_1$, $F = F_1 + \Delta F$, $x = x_1$, and $x = x_1 + \Delta x$ is shown to be equal to $(-\Delta F \Delta x)$. This is a familiar relation in thermodynamics.

J. H. Keenan, USA

2481. Black, C., Phase equilibria in mixtures of polar and nonpolar compounds, *AIChE J.* **5**, 2, 249–256, June 1959.

Author uses his earlier semiempirical relations [*Indust. Engng. Chem.* **50**, pp. 391, 403, 1958] to calculate the vapor imperfections and to correlate liquid-phase activity coefficients for binary mixtures of benzene and the *n*-aliphatic alcohols, methanol and pentanol. The paper shows that the modified Van Laar type of equation provides an adequate representation of the effect of composition on the activity coefficient for binary mixtures of benzene and alcohols. A cross correlation of the coefficients for these equations as a function of $1/T$ has been used to predict heat of mixing in good agreement with calorimetric data. From the excess free energies and the heats of mixing the excess entropy of solution has been obtained. Using a consistent set of cross-correlated coefficients both isothermal and isobaric vapor-liquid equilibria have been calculated without additional data.

Y. S. Touloukian, USA

2482. Koga, T., Model of molecular binary collision, *Physics of Fluids* **2**, 5, p. 580 (Research Notes), Sept./Oct. 1959.

2483. Shifrin, A. S., The viscosity of water steam under atmospheric pressure (in Russian), *Teploenergetika* no. 9, 22–27, Sept. 1959.

Results are given of an experimental investigation into viscosity of water steam at the range of temperatures from 149 to 866 C under atmospheric pressure. The method of two capillaries

used for investigation is described. Comparison is made with the results of other investigators. Equations are offered to show the dependence of water steam viscosity on temperature.

From author's summary

2484. Hord, R. A., Approximate composition and thermodynamic properties of nonionized nitrogen-oxygen mixtures, NASA TN D-2, 54 pp., Aug. 1959.

With ionization and nitric oxide formation neglected, analytic expressions are derived for the composition and thermodynamic properties of nitrogen-oxygen mixtures. The assumption of negligible nitric oxide is later removed and solution by iteration is used to prepare composition tables for the chemical species N, O, N_2, O_2, and NO. For densities sufficiently high for ionization to be negligible, the results of the study are applicable to 10,000 K.

From author's summary

2485. Mann, D. B., and Stewart, R. B., Thermodynamic properties of helium at low temperatures and high pressures, *ASME Trans.* **81**C (*J. Heat Transfer*), 4, 323–326, Nov. 1959.

The thermodynamic properties of helium have been compiled and correlated for a temperature range from 3.0 to 20 K for pressures to 100 atmospheres and for specific volumes from 5 to 800 liters per kilogram. The properties are presented on both the temperature-entropy and the enthalpy-entropy co-ordinate systems and include pressure, temperature, volume, entropy, and enthalpy.

From authors' summary

2486. Dahler, J. S., The molecular structure of liquids, *AIChE J.* **5**, 2, 212–222, June 1959.

Author presents an excellent, rather comprehensive and critical review of a most difficult subject area. The presentation is clear and in a form readable by conversant but non-specialist engineers who are interested in using the results for estimating purposes. The discussion deals primarily with the determination of the thermodynamical behavior of liquids. However, a survey is also given which treats simple nonassociated liquids of spherical, structureless molecules as far as transport phenomena are concerned. In summarizing the theoretical methods which have been developed to characterize the structure of liquids in equilibrium, the paper delves briefly into the cell theory first proposed by Eyring and Hirschfelder, Lennard-Jones and Devonshire and in substantial detail with the more rigorous mathematical treatments of Kirkwood.

Calculations on these theories are compared with those using the method of the superposition principle of Kirkwood et al. More recent developments, such as the hole theory of Eyring and Cernuschi, and the cell-cluster method of de Boer are mentioned briefly, concluding that the unavailability of numerical calculations on these theories makes it impossible to obtain an adequate test of their strength. The paper also discusses briefly experiments known as the Monte Carlo method. The results of available calculations on compressibility using the cell theory and superposition method are compared with some experimental data and the Monte Carlo numerical experiments of Rosenbluth and Rosenbluth.

Y. S. Touloukian, USA

2487. Andrews, D. H., Development of an automatic method for the determination of heat capacities of organic liquids and their recording on punch cards, AFOSR Chem. 40-12 (Johns Hopkins University, Dept. of Chem., Final Report), 20 pp., June 1959.

2488. Cox, R. A., and Smith, N. D., The specific heat of sea water, *Proc. Roy. Soc. Lond.* (*A*) **252**, 1268, 51–62, Aug. 1959.

There are many calculations in oceanography which involve the specific heat of sea water; this had not until now been determined to the precision desirable, and the temperature coefficient of C_p had not been measured.

An electrically heated calorimeter has been used to determine the specific heat of sea water over approximately the ranges of temperature and salinity occurring in nature. The results are considered accurate to 0.05%; previously accepted values are shown to be seriously in error. The temperature coefficient of C_p is shown to be positive for ocean water, while over the same range it is negative for pure water. An expression has been derived from which C_p can be computed over the ranges of 0 to 40 g/kg of salt and – 2 to 30 C, and tabulated values are given.

In testing the calorimeter the specific heat of ethanol was redetermined. Although incidental, the results are included as they are thought to be more reliable over the range of temperature covered than those previously published.

From authors' summary

2489. Rice, S. A., On the dilatational viscosity of simple dense fluids, *Physics of Fluids* **2**, 5, 579–580 (Research Notes), Sept./Oct. 1959.

2490. Wray, K. L., and Connolly, T. J., Thermal conductivity of clear fused silica at high temperatures, *J. Appl. Phys.* **30**, 11, 1702–1705, Nov. 1959.

The thermal conductivity of clear fused silica was measured over the temperature range 300–2100 K in an experiment which minimized radiative energy transport. This was a steady-state experiment involving the measurement of the electric current and voltage drop through a fine tungsten wire which was embedded along the axis of a cylindrical silica rod. The wire served both as a heating element and as a resistance thermometer. Thermal conductivities were calculated by graphical evaluation of the rate of change of electric power with temperature at different temperatures. The experiment yielded thermal conductivities between 2.6×10^{-3} and 2.9×10^{-3} cal/cm sec °K at room temperature, and between 4.5×10^{-3} and 5.5×10^{-3} cal/cm sec °K over the temperature range 1000–2100 K. From authors' summary

2491. Simoyu, M. P., Voulman, F. A., and Stavtzeva, S. A., Thermal design of a steam generating unit with the assistance of computing machine "Ural" (in Russian), *Teploenergetika* no. 9, 32–39, Sept. 1959.

2492. Ringo, B. C., Solar energy—the solar furnace and the civil engineer, *Civ. Engng.* **29**, 4, 39–41, Apr. 1959.

2493. Stratton, R., The figure of merit of a thermoelectric generator, *J. Elect. Control* **7**, 1, 73–76, July 1959.

Optimum conditions are deduced for a thermoelectric generator or refrigerator with *n*- and *p*-type semiconducting branches which have different physical parameters. The results are related in a simple manner to the previously calculated optimum conditions for the individual figure of merit of a single substance.

From author's summary

2494. Gettings, H., Prospects for thermoelectricity, *Missiles and Rockets* **5**, 26, 29–31, June 1959.

2495. Research on development of a method for measuring surface temperatures, AFOSR TR 58-88 (Institut de Recherche Scient. Techn. Centre Quest Final Rep. 55-13; ASTIA AD 162 109), 50 pp., Feb. 1959.

Wall temperatures have been measured from the change of color of some fluorescent lights. Measurements can be carried out up to 450 C. An automatic device has been built which records the ratio of radiation intensities at two wavelengths. The fluorescence is excited by mercury vapor. The intensity is measured by a photomultiplier in connection with a spectrograph. Two sulphides, those of zinc and cadmium, are of special interest and have been studied in detail. H. I. Behrens, Germany

2496. Thurlow, G. G., Some recent instruments for measuring gas temperatures and heat flow, *Brit. Coal Utilisat. Res. Assn. Bull.* **23**, 4, 129–137, Apr. 1959.

Review deals with some recent developments in instruments used to study heat transfer from flames. No attempt has been made to be comprehensive; the instruments described have been deliberately restricted to those of which the author has some direct knowledge. From author's summary

Heat and Mass Transfer

(See also Revs. 2153, 2154, 2155, 2168, 2170, 2404, 2471, 2478, 2490, 2494, 2495, 2496, 2578, 2602, 2607, 2645)

2497. Zarubin, V. S., One problem in nonstationary heat conduction, *ARS J.* **29**, 10, 773–776 (Russian Supplement), Oct. 1959.

Using Laplace transforms, author solves a simplified mathematical model of transient heat conduction in a cooled rocket nozzle. Solution for temperature in walls is given as infinite series of usual type, with suggestions for estimating eigenvalues. Example of calculation is given, but no comparison with measurements.

C. H. Barkelew, USA

2498. Ioffe, I. A., Plane nonstationary heat conduction problem for a semi-infinite body with an internal isothermal cylindrical source of heat, *Soviet Phys.—Tech. Phys.* **4**, 3, 369–374, Sept. 1959. (Translation of *Zh. Tekh. Fiz.* **29**, 3, 417–422, Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

A plane nonstationary heat-conduction problem for a semi-infinite body with an internal isothermal source of heat, and with constant temperature on the bounding plane, is solved. Expressions are given for the temperature field and for the heat flux.

The solution is obtained by the method of integral equations, and with one simplifying assumption. An approximate evaluation of the error of the solution is carried out.

L. Lapidus, USA

2499. Vodicka, V., Stationary temperature distribution in the walls of laminated pipe lines (in German), *J. Phys. Soc. Japan* **14**, 7, 959–965, July 1959.

In mathematical terms the author's problem consists in solving Laplace's equation in cylindrical coordinates with due regard for the boundary conditions. Appropriate methods of solution by Fourier expansion are well known. Author obtains solutions corresponding to given temperature distributions on the outer and inner surface of the tubes. They correspond also to the correct boundary conditions at the inter-laminar surfaces; alternative solutions are obtained satisfying a simplified inter-laminar boundary condition.

Resulting formulas are lengthy and their use for computational purposes is not obvious. There is no verbal discussion of the results and no example of their application.

R. Eisenschitz, England

2500. Wilkins, J. E., Jr., Conduction of heat in an insulated spherical shell with arbitrary spherically symmetric sources, *SIAM Rev.* **1**, 2, 149–153, July 1959.

Author derives general solution for Laplace transformed equation in case where the heat sources vary arbitrarily with radius but are independent of time. Inversion is carried out only at the inner radius of the shell, by expanding in Maclaurin series under an approximation which in effect places outer radius at infinity and so is suited for short times. Application is made to heating of a nuclear reactor shell.

S. Paterson, Scotland

2501. Borbely, S., Investigation in connection with nonlinear heat conduction (in Hungarian), *Magyar Tud. Akad. Musz. Tud. Oszt. Kozl.* **23**, 3/4, 261–286, 1959.

This is a rather sketchy account of computational and experimental work on transient temperature distributions in heated cylinders. Nonlinearity of the problem arises from the strong temperature-dependence of physical properties. It is doubtful whether, if the author had had access to a high-speed computer, the computational problem would have seemed as formidable as it did. A wide discrepancy between calculated and observed temperature distributions led the author to infer that the conventional definition of thermal conductivity may be inadequate for study of unsteady-state processes. Reviewer doubts if a rather primitive experiment, such as this, is an adequate basis for such an inference.

R. Gardon, USA

2502. Brewer, D. F., and Edwards, D. O., The heat conductivity and viscosity of liquid helium II, *Proc. Roy. Soc. Lond. (A)* **251**, 1265, 247–264, May 1959.

Measurements have been made in glass capillary tubes of 52 and 108μ diameter, in the temperature range from 1.15 to 2.15 K. For sufficiently small temperature gradients the thermal resistance is independent of the heat flow and is caused solely by the viscosity of the normal fluid, η_n. This viscosity has been calculated from the measured thermal resistance data with the use of the existing entropy values, and the results from the two tubes are in very good agreement except for a small deviation at low temperatures which is attributed to slip. The viscosity at the saturated vapor pressure, when corrected for slip, agrees closely with the results obtained by the rotating cylinder viscometer but does not agree with the oscillating disk experiments. The variation of η_n at low temperatures follows the theory of Landau & Khalatnikov if Δ/k is taken as 8.9 K, but the measured values of the slip correction are slightly larger than would be expected from the theoretical phonon and roton mean free paths.

In the 52μ tube the measurements have been extended up to the solidification pressure so as to give η_n as a function of density. Near the lambda line η_n increases rapidly with density, but at low temperatures the variation is quite small and it is found that the contribution from the rotons is almost independent of density.

From authors' summary

2503. Danilovskaya, V. I., Approximate solution of the problem of stationary temperature field in a thin shell of arbitrary shape (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 9, 157–158, Sept. 1957.

2504. Harman, T. C., Cahn, J. H., and Logan, M. J., Measurement of thermal conductivity by utilization of the Peltier effect, *J. Appl. Phys.* **30**, 9, 1351–1359, Sept. 1959.

A special technique for the accurate measurement of thermal conductivity is presented using the Peltier heat to maintain a temperature gradient along a given specimen. Simple measurements permit computation of the absolute values of thermoelectric power, thermal conductivity and electrical resistivity. The technique was tested experimentally at 300 K only, but the opinion is expressed that the technique is valid up to 1000 K. The technique appears to have particular application for materials of low thermal conductivity and small dimensions. J. F. Lee, USA

2505. Stogryn, D. E., and Hirschfelder, J. O., The initial pressure dependence of thermal conductivity and viscosity, Univ. of Wisconsin, Naval Research Laboratory, Dept. of Chemistry WIS-ONR-36, 34 pp., Apr. 1959.

Both thermal conductivity and viscosity of real gases depend on pressure and may be expressed as power series in pressure. Authors calculate first-order terms in such an expansion by assuming

spherically symmetric interaction potentials, considering the two effects of molecular association and collisional transfer. Discussion of previous work is given; also, comparison of present theory with experiment shows moderately good agreement.

C. E. Pearson, USA

2506. Newcomb, T. P., Heat flow research: Analysis of brake drum temperatures in racing cars, *Engineering* **187**, 4864, 709–711, May 1959.

2507. Dennis, S. C. R., Mercer, A. McD., and Poots, G., Forced heat convection in laminar flow through rectangular ducts, *Quart. Appl. Math.* **17**, 3, 285–297, Oct. 1959.

The forced steady-state convection through ducts under constant pressure is examined by method similar to Galerkin's. Heat-transfer equation is reduced to that of a plane membrane by use of the assumption that $1/Pe^2$ (Pe–Péclet number) is negligibly small, and the solution is obtained in terms of the eigenfunctions of the membrane equation. For rectangular cross section, results are numerically evaluated and compared with the theoretical and experimental results of Clark and Kays [AMR **6**(1953), Rev. 1059]. Some possible reasons for the discrepancies are discussed.

L. S. Rintel, Israel

2508. Sabersky, R. H., Recent developments in convective heat transfer, *ARS J.* **29**, 5, 325–331, May 1959.

2509. Kudryashev, L. I., and Vvedenskaya, L. A., A controlled, and a controlled within limits, temperature regime and their applications to the experimental determination of the coefficient of heat emission and resistance when bodies of arbitrary form are heated (in Russian), *Sb. Nauchn. Trudi Kuibyshevsk. Industr. In-ta* no. 7, 47–59, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 534.

An evaluation was made of the influence on the heat exchange of a nonstationary thermal field resulting from the insertion of an α-calorimeter into the flow of a viscous incompressible liquid. Using a controlled regular thermal system the thermal emission was investigated of pipes of round, square and triangular transverse sections, the tubes being subjected in an aerodynamical tube to a flow of air at R numbers = to $10^3 - 4 \times 10^4$. It was shown that the angle of rotation of the pipe in relation to the direction of the oncoming air flow had no effect on the mean coefficient of heat emission. By making use of the previously [L. I. Kudryashev, *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 9, 1309–1316, 1953] obtained link between the coefficients of resistance and heat exchange when bodies are flown about with breaks, authors were able to determine the coefficients of resistance for the same pipes. The results obtained, which were found to be in agreement with other relevant studies, were put forward in the form of relations $N = N(R)$ and $c_f = c_f(R)$.

N. A. Anfimov

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

2510. Kubanskii, P. N., The effect of acoustic streaming on convective heat exchange, *Soviet Phys.—Acoustics* **5**, 1, 49–55, Aug. 1959. (Translation of *Akust. Zh.* **5**, 1, 51–58, Jan./Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

When solid bodies vibrate in compressible fluids, considerable increases in heat transfer arise, compared with fixed body case. Paper explains this result in terms of acoustic streaming. Experiments with fixed cylinder in presence of finite amplitude standing sound wave are reported and discussed.

N. Curle, England

2511. Adams, M. C., Recent advances in ablation, *ARS J.* **29**, 9, 625–632, Sept. 1959.

Author presents a timely introduction to the principles of ablation as applied to short-time heating problems of the type encountered in the re-entry of a ballistic missile nose-cone into the atmosphere. Ablation represents a major advance over the simple heat sink as a means of absorbing aerodynamic heating.

In the ablation process, material is removed from the heated body by evaporation, following an initial heat-up period which brings the surface up to a sufficiently high temperature. Plastics and glasses are generally used as ablating materials. Use of metals or graphite is impeded by their higher thermal conductivity, which makes them conduct heat away from the surface and act as a conventional heat sink rather than put most of the heat into ablation at the surface.

Author considers the interaction between the ablating surface and the external gas boundary layer for three cases: melting without evaporation (which is least interesting from a practical viewpoint), sublimation (the other extreme from melting), and combined melting and sublimation.

Test data are presented for Teflon, quartz, and fiber glass, and examples of applications of ablation are considered for satellite re-entry and rocket nozzles. An extensive bibliography of recent unclassified reports is included.

A. R. Gruber, USA

2512. LeFur, B., Heat transfer and recovery factor in a laminar boundary layer with arbitrary pressure gradient and wall temperature distribution, *J. Aero/Space Sci.* **26**, 10, 682–683 (Readers' Forum), Oct. 1959.

Author extends Lighthill's method to include friction heating. Although an approximation for the wall shear stress is used, results are in good agreement with calculations based on exact values.

A. Sesonske, USA

2513. Cresci, R. J., MacKenzie, D. A., and Libby, P. A., An investigation of laminar, transitional, and turbulent heat transfer on blunt-nosed bodies in hypersonic flow, WADC TN 59–119 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech.; ASTIA AD 214 617), 50 pp., Apr. 1959.

Laminar, transitional and turbulent heating rates have been measured by means of the shrouded model technique. The Reynolds number was varied over a ninefold range; the enthalpy ratio (stagnation to wall) varied from 2.3 to approximately 1.5. Two different pressure distributions were imposed on the model, which consisted of a spherically capped cone.

The experimental data are compared to the laminar hypersonic boundary-layer theory and shown to be in good agreement on the conical portion of the model. On the spherical portion the data are approximately 20% higher than the theoretical prediction. Some of this discrepancy can be attributed to radiation to the nose of the model.

The fully developed turbulent heat-transfer data are compared to two theories: (1) a relatively simple turbulent theory which is based on recent theoretical work and which takes into account the upstream history of the boundary layer; and (2) the flat-plate reference-enthalpy theory, which depends on only "local" conditions. Although both theories are in reasonable agreement with the data, the latter method is simpler and somewhat more accurate.

For transitional flow the theory mentioned first can be readily modified in order to permit reasonable estimates of transitional heat transfer to be obtained. On this basis it is possible to estimate laminar, transitional and fully developed turbulent heat transfer under hypersonic blunt-body conditions.

The behavior of transition Reynolds number based on momentum thickness is also discussed and shown to be in quantitative agreement with recent shock-tube measurements.

From authors' summary

2514. Golovanov, O. M., Application of the theory of similarity to the derivation of the equation for the hydrodynamical theory of heat exchange during the flow about of bodies with breaks (in

Russian), *Sb. Nauchn. Trudi Kuibyshevsk. Industr. In-ta* no. 7, 75–79, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 524.

It was shown, with the aid of the methods of the theory of similarity, that the system of differential equations determining the heat exchange and flow in the wake of a body can be simplified if the distance from the body flown about along the wake in R numbers is adopted as the characteristic dimension. Then, if the R number is sufficiently large, the influence of the internal viscosity and of the heat conductivity can be disregarded. Correlations are obtained linking the body's resistance with the heat exchange between the flow and the body. E. N. Boudarev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2515. Vetter, H. C., Note on the calculation of equilibrium skin temperatures, *J. Aero/Space Sci.* **26,** 11, 757–758 (Readers' Forum), Nov. 1959.

This note presents a method for the rapid estimation of equilibrium skin temperatures that result from aerodynamic heating in both the real-gas and ideal-gas regimes. Heretofore the calculation of equilibrium temperatures has relied on a graphical or analytical determination of the roots of a fourth-order equation. The present method reduces the problem to the reading of a design chart for ideal-gas flow and to a quickly converging iteration method using the same design chart for real-gas flows.

From author's summary

2516. Kozlova, A. N., Temperature distribution inside an inclined tube filled with air, in the presence of free convection, *Soviet Phys.—Tech. Phys.* **4,** 3, 285–289, Sept. 1959. (Translation of *Zh. Tekh. Fiz.* **29,** 3, 319–324, Mar. 1959 by American Institute of Physics, New York, N. Y.)

Paper presents typical selection from more than 100 series of wall-temperature measurements in insulated tubes at least 30 diameters in length and closed below heating element at lower end. Empirical expression is obtained which approximates longitudinal distribution of nondimensional temperature as function of angle of tube inclination and thermal properties of fluid and boundary. Author notes that difference exists between distribution functions for liquids and gases. H. Rouse, USA

2517. Baron, J. R., and Finston, M., Free convection past a vertical flat plate: some numerical results, Mass. Inst. Technol., Naval Supersonic Lab. TR 269, 23 pp., Mar. 1959.

Exact solutions are presented in numerical form for the free convection flow past a vertical plane surface of nonuniform temperature. From authors' summary

2518. Elder, R. A., Thermal density underflow design and experience, Proceedings, Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16–18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 73–89.

Author gives results of operation of three structures designed to withdraw only underlying cold water from rivers, where thermally stratified flow happens. Structures are of skimmer-wall type and belong to three steam plants of which only one was operating long enough: five years. Design of skimmer-walls was made according to curves furnished by M.I.T. tests [Harleman et al., *Proc. Amer. Soc. Civ. Engrs.* **84** HY2 (*J. Hydr. Div.*, Pap. 1587, Apr. 1958].

Author suggests that results in the long-operating plant may agree with M.I.T. curves if water temperatures in the pump intake are corrected for increase in the channel. Reviewer believes that other data, particularly temperatures near skimmer-walls are needed.

Stability of stratified flow was found not to be disturbed from sudden shifts in withdrawal rate. Author suggests caution in employing skimmer-wall structures in rivers in which silting is feared or water temperatures of upper layers might decrease to 40 F during the winter. M. Viparelli, Italy

2519. Kudryashev, L. I., and Ipatenko, A. Ya., Effect of free motion on the heat transfer coefficient for flow around a sphere in the region of small Reynolds numbers, *Soviet Phys.-Tech. Phys.* **4,** 3, 275–284, Sept. 1959. (Translation of *Zh. Tekh. Fiz.*, **29,** 3, 309–319, Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Theoretical and experimental investigation is reported of relation between Nusselt, Grashof and Reynolds numbers when the external fluid (air) has velocity vertically upwards or downwards. Fair agreement is claimed. Reviewer believes theory, which employs integral method, contains too many arbitrary physical and mathematical assumptions for credence. Equations [1] and [13] appear to contain contradictory definitions of thermal boundary-layer thickness. D. B. Spalding, England

2520. Green, L., Jr., and Nall, K. L., Experiments on porous-wall cooling and flow separation control in a supersonic nozzle, *J. Aero/Space Sci.* **26,** 11, 689–697, Nov. 1959.

A two-dimensional supersonic nozzle of fixed divergence was cooled by injection of fluid through one porous wall. Quantity of injection was varied by changing the injection pressure through walls of different known porosities. Stream-side porous wall temperature, calculated from injection-side wall temperature and flow full temperatures, is properly correlated to injection flow. It is found that this wall temperature could be brought closely to coolant temperature at a coolant flow of a few per cent of main flow. Schlieren photographs indicate that flow separation is favored by injection. Authors conclude that this fact could be used to control jet deflection. L. S. Dzung, Switzerland

2521. Richards, H. T., Evaluation of transpiration-cooled turbine blades with shells of "Poroloy" wire cloth, NASA Memo 1-29-59E, 17 pp., May 1959.

Permeability of airfoil shell and soundness of structure were examined on a group of strut-supported, transpiration-cooled turbine blades. The blade shells were formed of "Poroloy," a woven sintered wire material. Two blades were investigated for shell permeability. Four were used to evaluate durability in a turbojet engine at an average turbine-inlet temperature of approximately 1670 F and a turbine tip speed of approximately 1305 fps. The porous-shell temperature was maintained below 1050 F. Two additional blades were mechanically sectioned to examine the condition of shell-to-supporting strut welds.

From author's summary

2522. Glaser, H., Thermal conductivity and diffusion of water vapor in insulating materials (in German), *Kältetechnik* **10,** 3, 86–91, Mar. 1958.

Continuity of vapor flow requires that there be no break in the curve representing the vapor pressure if condensation of vapor occurs. In such a case the change of temperature and vapor pressure influence each other. The actual conditions in the insulation wall may be mathematically expressed, and are discussed for a particular case. Experimental results are in substantial agreement with the new theory. From author's summary

2523. Farkas, G., and Varga, P., Determination of the emissivity of a radiating cavity (in Hungarian), *Magyar Fiz. Foly.* **7,** 1, 37–46, 1959.

Intent on designing an optimal radiating cavity, the authors consider the difference between the intensities of radiation emitted by a cavity and an ideal blackbody radiator. In particular, account is taken of the fact that the walls of the cavity are not perfectly diffuse reflectors. R. Gardon, USA

2524. Schlousener, R. A., and Corey, A. T., The role of hysteresis in reducing evaporation from soils in contact with a water table, *J. Geophys. Res.* **64,** 4, 469–475, Apr. 1959.

Evaporation studies were conducted on three soil types in contact with a water table. For conditions of high evaporativity or increased depth to the water table, it was found that evaporation from the soils was not always in proportion to the rate of evaporation from a free-water surface. Under some conditions there was an inverse relation between evaporation from the soils and that from the free-water surface.

Analysis of upward movement of water from a water table in the absence of hysteresis effects does not provide a satisfactory explanation for this inverse relation.

A capillary tube model is used to explain qualitatively these results on the basis of reversals of changes in pressure in the soil water. This hysteresis phenomenon is believed to be responsible for reducing evaporation from soils in contact with a water table.

From authors' summary

2525. Vyshenskii, V. V., Investigation of heat emission of particles in a straight flow by the analogy method with diffusion (in Russian), *Izv. Akad. Nauk KazSSR, Ser. Energ.* no. 1 (12), 75–84, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 533.

A study was made of heat emission in the conditions described in the title. Napthalene balls with initial dimensions of from 3 to 9 mm fastened on a special suspender bracket were subjected to a flow of air with a velocity of from 2.7 to 3.6 m/sec at an air temperature of 60–80° (the final dimension of the ball was ~0.9 mm). In these conditions the R number varied in the range of 120–16,500. The intensity of the evaporation was calculated by the decrease in the diameter of the ball, determined by photography through a microscope. In order to obtain an even diminution of the ball's dimensions a slow rotation was imparted to the ball (velocity on the surface $(0.2–1.9) \times 10^{-3}$ m/sec), which had no effect, as was shown experimentally, on the speed of the process. Analysis of the results of the experiment enabled the author to derive an expression $N = 0.62\ R^{0.5} P^{0.38}$, which agreed well with the data of D. I. Vyribov and A. P. Sokolskii.

G. A. Varshavskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2526. Zenkevich, B. A., Use of the principle of similarity for the critical thermal loading during the constrained motion of a liquid (in Russian), *Atomnaya Energiya* **4,** 1, 74–77, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 548.

The results are communicated of the investigation on the effect of transition from bubble boiling to film boiling, known under the name of crisis boiling. A short exposition is given of the theoretical concepts, based on a hydrodynamical model of the phenomenon. A quantitative relation is proposed which embraces satisfactorily the results of the author's own experiments (in the range of pressures 100–200 atm, of water velocity 0.5–8 m/sec, of underheating 2–100°) and those of Buchberg [H. Buchberg et al, Heat transfer and fluid mechanics Inst., Stanford, California, June 1951]. It is noted that for a small velocity and negligible underheating of the water smaller values can be obtained for the critical load than in the case where boiling is taking place in a large space. The proposed equation is derived on the type of

$$K = f(K_1,\ K_2 m\ R)$$

where

$$K = \frac{q_{cr}}{r}\sqrt{\frac{\nu}{\sigma g\, W_g}}, \qquad K_1 = \frac{\gamma''}{\gamma H}$$

$$K_2 = \frac{i' - i'H}{r}, \qquad R = \frac{W}{\nu}\sqrt{\frac{\sigma}{\gamma' - \gamma''}}$$

q_{cr} is the critical load, g is the acceleration of the force of gravity, r is the heat of steam formation, W is the mean linear velocity of the water, W_g is the gravimetric velocity, ν is the kinematic viscosity, σ is the surface tension, γ is the specific gravity, i is the enthalpy. Strokes above the symbols indicate the parameters of the liquid (one ′) and the steam-forming phase (two ″) in a state of equilibrium; index H indicates the parameter of the underheated water at the outlet of the working portion. The existence is pointed out of a region of similarity relative to criterion R (which is a modified Reynolds number) when the influence of the forces of viscosity during reduced velocity begins to make its appearance earlier as the pressure drops and the underheating is reduced. The concrete form of the calculation equation is notable for its great complexity.

A. A. Gukhman

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2527. Pearce, D. C., An analysis of frost action beneath cold storage warehouses, *Trans. Engng. Inst., Canada* **2,** 4, 153–156, Dec. 1958.

The temperature distribution beneath a cold storage warehouse (of slab-on-grade construction) has been determined approximately by analytical methods. The elimination of the possibility of (frost action) damage by the introduction of heat beneath the floor insulation is shown to be economically feasible. The design of a heating system to prevent soil freezing is discussed in detail.

From author's summary by J. G. Bartas, USA

2528. Zhokhovskii, M. K., On certain principles pertaining to the melting of substances and their significance for a high pressure scale, *Measurement Techniques* no. 2, 138–144, Aug. 1959. (Translation of *Izmeritel'naia Tekhnika,* no. 2, 16–21, Mar./Apr. 1958 by Instrument Society of America, Pittsburgh, Pa.)

Author is concerned with the variation with pressure of the melting temperature of a number of pure substances. The twenty-eight substances quoted are those for which data have been obtained experimentally by Bridgman. (The pressure ranges differ and the maximum pressure is 40,000 kg. f/cm², e.g. 1,000 to 12,000 kg. f/cm² and 15,000 to 35,000 kg. f/cm².)

Applying the Clausius-Clapeyron equation, author obtains an empirical relation between ρ and T, similar to the Simon equation, in which he identifies one constant as $\lambda/\Delta v$ at normal melting temperature. λ is the latent heat of fusion and Δv is the change of volume. For any one substance $\ln(\lambda/\Delta v)$ is a linear function of the melting temperature T.

The pT equation obtained is proposed as the basis for a thermodynamic scale for high pressure. Reviewer believes that in this particular form the equation will be only of academic interest until λ is directly determined by experiment.

T. D. Patten, Scotland

2529. Kyner, W. T., On a free boundary value problem for the heat equation, *Quart. Appl. Math.* **17,** 3, 305–310, Oct. 1959.

In a previous paper W. L. Miranker solved, using a method due to I. Kolodner, the one-dimensional Stefan's problem, formulated as follows: Solve the heat conduction equation $U_{xx} = U_t$, $0 < X < R(t)$, where initial temperature distribution $U_0(X)$ is prescribed in $0 < X < A = R(0)$, heat flux at $X = 0$ is a prescribed function of time, temperature at the melting front (i.e., at $R(t)$) is zero, and the melting condition $U_x(R, t) = -dR/dt$ is satisfied. Author extends earlier work, using an iterative method modeled after Evans, to the case where the restriction $A > 0$, $dU_0(A)/dX < 0$ (i.e., there is already a molten region present at $t = 0$) is eliminated.

G. Horvay, USA

2530. Kynor, W. T., An existence and uniqueness theorem for a nonlinear Stefan problem, *J. Math. Mech.* **8**, 4, 483–498, July 1959.

Author gives existence and uniqueness proof for problem of preceding review, generalized to the case where material properties are time, position and temperature dependent, by establishing an integral equation for $R(t)$, making use of Schauder's fixed-point theorem and of the maximum principle of L. Nirenberg.

G. Horvay, USA

2531. Murray, W. D., and Landis, F., Numerical and machine solutions of transient heat-conduction problems involving melting or freezing, Part I: Method of analysis and sample solutions, *ASME Trans.* **81**C (*J. Heat Transfer*), 2, 106–112, May 1959.

See AMR **12**(1959), Rev. 2039.

2532. Ostroumov, G. A., Theory of thermal processes during liquid drawing of wire under steady-state conditions, *Soviet Phys.—Tech. Phys.* **4**, 2, 208–214, Aug. 1959. (Translation of *Zh. Tekh. Fiz.* **29**, 2, 239–247, Feb. 1959 by American Institute of Physics, New York, N. Y.)

Authors consider a liquid metal jet leaving (at $Z = 0$ and velocity V) a furnace, having the temperature of the furnace as exit temperature. In the region $Z > 0$ the cylindrical jet is surface-cooled (heat-transfer coefficient is prescribed). Author determines the temperature distribution as function of Z and r, restricting himself primarily to the slowest decaying term of an infinite series. He also treats the case where, at $Z = 0$, heat of fusion release occurs (the jet freezes), and applies the results to the case of zone melting. Checking of paper is difficult, because author states only results and gives no details of analysis.

G. Horvay, USA

2533. Scala, S. M., and Sutton, G. W., Energy transfer at a chemically reacting or slip interface, *ARS J.* **29**, 2, 141–143 (Tech. Notes), Feb. 1959.

Authors discuss the proper boundary condition reflecting the energy balance of heat conduction, diffusion and mass transfer rate at the wall, for flows of multi-component gas mixtures over a chemically reacting surface.

S. -F. Shen, USA

2534. Cutting, J. C., Fay, J. A., Hogan, W. T., and Moffatt, W. C., Heat transfer in dissociated combustion gases, AFOSR TR 59-78 (Mass. Inst. Technol., Dept. Mech. Engng.), 44 pp., July 1959.

A report on a series of experiments and theoretical calculations to determine heat-transfer rate from the hot gas behind a detonation wave. A constant current fine wire (platinum or tungsten) heat-transfer gage was placed normal to the 1½-inch diameter shock tube walls and was swept by detonations in stoichiometric H_2—O_2 mixtures at various initial pressures and in C_2H_2—O_2 mixtures of differing compositions at 1-atmosphere pressure. The effect of a thin surface coating of iodine was also assessed. The theoretical treatment is based on stagnation point heat-transfer theory and uses calculated transport properties at the gage with the assumption of a noncatalytic gage. Good agreement was found in pressure and concentration dependence of heat transfer. However, measured heat transfer is less than the theoretically expected value. Also heat transfer was two to three times less for the iodine gage than the bare gage.

R. A. Strehlow, USA

Combustion

(See also Revs. 2478, 2505, 2534, 2554, 2555)

2535. Wright, F. H., Bluff-body flame stabilization: blockage effects, *Combustion and Flame* **3**, 3, 319–337, Sept. 1959.

Paper presents results of a study on flame stabilization by thin flat plate water-cooled flame holders. Experiments were performed at 339 K with homogeneous mixtures of a gasoline-like hydrocarbon and air flowing in a 1-in. × 4-in. duct at Mach numbers up to about 0.55.

Author believes that his experiments demonstrate more convincingly than past work that flow patterns about bluff body, and accordingly also flame blowoff, depend specially on fluid dynamic variables. Characteristic chemical time, which summarized combustion chemistry effects, appears not to be influenced by gross fluid dynamics parameters (Reynolds number, Mach number, blockage) and is to be taken into account as an independent variable.

Conclusions drawn from a free-stream theory supplemented by some experimental results lead author to a practical result that "the maximum blowoff speed occurs at a relatively low blockage ratio."

N. Manson, France

2536. Bartkowiak, A., Lambiris, S., and Zabetakis, M. G., Flame propagation through kerosine foams, *Combustion and Flame* **3**, 3, 347–353, Sept. 1959.

Under certain conditions, liquid fuels such as kerosine may form foams flammable at temperatures below the flash point of the fuel. Thomas found that at one atmosphere pressure kerosine foam would not burn in air but would burn in oxygen-enriched air. Since it appeared possible to produce flammable foams with certain combustible liquids in air, an investigation was undertaken to determine the conditions under which these foams would be formed. It was found that flammable foams could be produced quite readily with kerosine and other light oils in air and in nitrogen- and carbon dioxide-enriched air. Because these foams constitute a potential gas explosion hazard, a series of experiments was conducted in various enclosures to determine the maximum pressures developed when these foams were ignited. Tests were conducted in containers ranging from about 0.1 to 10^3 ft.^{3} The maximum pressure was found to be a function of the amount of foam, free space above the liquid surface and number of points of ignition. Maximum pressures of 35 lb/in.^{2} gauge were encountered in small containers. The rates of pressure rise were considerably smaller than those encountered with explosions through combustible vapor-air mixtures. Photographs of the flame propagating through kerosine foam in air show that the foam collapses and forms droplets as the flame approaches. The vapor around these droplets is then ignited and in turn acts as an ignition source to continue the propagation.

From authors' summary

2537. Wright, F. H., Multiple flameholder arrays: flame interactions, *ARS J.* **29**, 2, 143–144 (Tech. Notes), Feb. 1959.

2538. Larisch, E., Interactions of detonation waves, *J. Fluid Mech.* **6**, 3, 392–400, Oct. 1959.

The interaction of oblique discontinuities when detonation waves may occur is analyzed using Landau's theory of incident and emerging waves. A full list of possible interactions is given, and the use of polar diagrams for the quantitative solution of interaction problems is illustrated.

K. Stewartson, England

2539. Troshin, Yu. K., Points on lower Hugoniot curve describing combustion modes in jet engine chambers, *ARS J.* **29**, 10, 750–756 (Russian Supplement), Oct. 1959.

Author shows that, with idealized assumptions, the lower branch of the Hugoniot curve describes combustion intensities in tubes, including rocket combustion chambers. A relationship is shown between a point on this curve and the ratio of chamber cross-section area to nozzle throat area. Expressions are derived allowing rough approximations of rocket motor performance and internal combustion chamber parameters, including the turbulent flame area, flame-front velocities, and shock-wave velocities. The latter may be helpful in studying combustion instabilities.

H. Faught, USA

2540. Sugawara, S., and Michiyoshi, I., The thermoaerodynamical analysis of combustion gas flow, 1st Report, *Bull. JSME* **2,** 5, 138–143, Feb. 1959.

2541. Smith, C. T., Application of cyclone-furnace firing to industrial boilers, ASME Semiann. Meet., St. Louis, Mo., June 1959. Pap. 59-SA-53, 20 pp.

2542. Drell, I. L., and Belles, F. E., Survey of hydrogen combustion properties, NACA Rep. 1383, 34 pp., 1958.

This literature digest of hydrogen-air combustion fundamentals presents data on flame temperature, burning velocity, quenching distance, flammability limits, ignition energy, flame stability, detonation, spontaneous ignition, and explosion limits. The data are assessed, recommended values are given, and relations among various combustion properties are discussed. New material presented includes: theoretical treatment of variation in spontaneous-ignition lag with temperature, pressure, and composition, based on reaction kinetics of hydrogen oxidation; and calculated adiabatic flame temperatures over the entire hydrogen-air composition range for 0.01 to 100 atmospheres and initial temperatures of 0 to 1400 K.

From authors' summary

2543. Williams, M. R., and Greenwood, S. W., The effect of combustor outlet temperature profiles on ramjet thrust, Coll. Aero. Cranfield, Note 59, 22 pp., July 1957.

The desirability of obtaining an even distribution of temperature at the outlet of a ramjet combustor is indicated theoretically. Results of experiments on a particular combustion system over a limited range of conditions using a series of mixers are presented. The results suggest that mixers are desirable for high Mach number ramjets operating at low overall fuel-air ratios.

From authors' summary

2544. Palmer, H. B., Burning rate of an H-atom propellant, *ARS J.* **29,** 5, 365–366 (Tech. Notes), May 1959.

2545. Caracristi, V. Z., and Mumper, H. D., Combustion of crushed, dried Texas lignite and char in steam-power boilers, ASME Semiann. Meet., St. Louis, Mo., June 1959. Pap 59-SA-36, 15 pp.

Symposium of characteristics of flames and of gaseous and liquid fuels, *Indust. Engng. Chem.* **51,** 4, Apr. 1959.

2546. Wilson, C. W., and McGowan, G. E., Predicting burner performance and flame stability in domestic gas appliances, 556–559.

2547. Wilson, C. W., Flash back in domestic gas appliances, 560–563.

2548. Fine, B., Effect of initial temperature on flash back of laminar and turbulent burner flames, 564–566.

2549. Weil, S. A., Predicting burning velocities of lean hydrocarbon flames, 567–569.

2550. Grumer, J., and Harris, M. E., Smoke limits of bunsen burner ethylene-air flames, 570–572.

Prime Movers and Propulsion Devices

(See also Revs. 2473, 2478, 2504, 2535, 2539, 2666)

2551. Krebs, R. P., and Hart, C. E., Analysis of flow-system starting dynamics of turbopump-fed liquid-propellant rocket, NASA Memo 4-21-59E, 45 pp., Apr. 1959.

Rocket performance depends greatly on starting events. Article reports analog computer study of period when fuel flow is being increased from value just sufficient to maintain combustion to full design value for rocket of about 300,000-pounds thrust. Two cases are considered: (1) turbine pressure ratio constant with external fuel supply and (2) "bootstrap," with fuel supply from pump discharge after start with external help. Results show that speed-response time, flow-response time, and pressure loss from acceleration and friction in pump intake pipe depend on rotor inertia, basic turbine performance, and geometry of system; two parameters are developed to express this dependence. Although results require real-life check, they should be useful in the meantime as guide to rocket designers. C. W. Smith, USA

2552. Bragg, S. L., Changes in the density and temperature of liquid propellants in rocket engine supply systems, *ARS J.* **29,** 9, 672–674 (Tech. Notes), Sept. 1959.

The basic thermodynamic relations are used to derive equations for the changes in propellant density and temperature in rocket engine supply systems. It is shown that in a pump with pressure rise ΔP, these changes are given by

$$-\frac{\Delta\rho}{\rho}=\frac{\Delta V}{V}=\Delta P\left[\frac{\alpha V}{C_p}\left(\frac{1-\eta}{\eta}+\alpha T\right)-\beta_T\right]$$

$$\Delta T=\frac{V\Delta P}{C_p}\left(\frac{1-\eta}{\eta}+\alpha T\right)$$

where the symbols have the conventional meanings. In a pipe in which friction causes a pressure drop $-\Delta P$

$$-\frac{\Delta\rho}{\rho}=\frac{\Delta V}{V}=-\Delta P\left[\frac{\alpha V}{C_p}(1-\alpha T)+\beta_T\right]$$

$$\Delta T=\frac{V(-\Delta P)}{C_p}(1-\alpha T)$$

Numerical values for typical propellants show that these changes, although small, are not insignificant.

From author's summary

2553. Kotlyar, I. V., Method for the calculation of the universal characteristics of a gas or steam turbine (in Russian), *Trudi Kharkovsk. Politekhn. In-ta* **16,** 191–198, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 278.

A method is put forward for the calculations for the performance of single-stage and multi-stage turbines with given geometrical parameters. The method utilizes the known formulas for linking up inputs and pressures with subcritical and hypercritical discharges and empirical relations. The calculation is carried through progressively from the outlet section to the inlet section, thus reducing the necessary number of progressive approximations. Results are given for the comparison between the calculations and the experimental data for a single-stage turbine. This gives an opportunity, in the author's opinion, to judge the merits and promise of the method. N. A. Kolokoltsov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2554. Heidmann, M. F., Propellant vaporization as a criterion for rocket-engine design; experimental effect of chamber diameter on liquid oxygen-heptane performance, NASA TN D-65, 22 pp., Sept. 1959.

The effect of combustor gas velocity on the performance of a pair of impinging heptane jets reacting in a highly atomized oxygen atmosphere was evaluated in a nominal 200-pound-thrust combustor. Contraction-ratio changes resulting from variations in chamber diameter were used to vary combustor gas velocity. Characteristic

velocity as a function of chamber length was obtained for four diameters corresponding to contraction ratios of 2.17, 3.60, 6.40, and 11.0. The study was made with a single injector and at one propellant-flow condition.

In combustors less than 10 inches long, highest performance was obtained with the large-contraction-ratio combustors. In chambers greater than 10 inches long, the reverse trend of performance with contraction ratio was observed. A direct comparison of this experimental effect and the analytical effect presented in the literature showed that the experimental reversal occurred in a longer chamber and at higher performance than predicted. In the high-performance region the increase in performance with a decrease in contraction ratio was similar in magnitude to that indicated analytically.

From author's summary

2555. Chaiken, R. F., A thermal layer mechanism of combustion of solid composite propellants: Application to ammonium nitrate propellants, *Combustion and Flame* **3,** 3, 285–300, Sept. 1959.

Rate of combustion of a spherical oxidizer pellet embedded in a binder matrix is analyzed by equating heat required to gasify the pellet surface to heat transferred from surrounding hot combustion gas. Neglecting conduction in the solid phase and assuming constant flame and surface temperatures, the equation relates the linear regression rate of oxidizer surface v to a thickness δ of the thermal layer around the surface, with surface temperature T_s as eigenvalue.

To solve for the eigenvalue, v is related to T_s by means of an Arhennius-type expression [see also AMR **12**(1959), Revs. 3612 and 4722], whereas δ is related to the average gas velocity and the reaction rate or half-life by analyzing mass flow through the gas layer simplified to consist of an inner shell of expanding gaseous reactants surrounded by a zone of complete reaction. An additional relation is obtained by considering the approximate time-dependence of the thermal layer thickness δ surrounding a sphere immersed in a flowing gas, so that the gas velocity in the thermal layer can be eliminated and δ related to the half-life directly. Combining these results yields the surface temperature T_s and its temperature dependence, based on second-order reaction kinetics, as function of the reaction rate.

Numerical computations are performed for ammonium nitrate propellants. Comparison with experiment [AMR **12**(1959), Rev. 4722] shows that analysis is reasonable in view of simplifications and possible error in data.

R. A. Stern, USA

2556. Willinski, M. I., Beamed electromagnetic power as a propulsion energy source, *ARS J.* **29,** 8, 601–603 (Tech. Notes), Aug. 1959.

A novel rocket propulsion system, utilizing an external energy source in the form of beamed electromagnetic power, is proposed. A comparison is made with solar energy. Its application to propulsion fluid heating and electric rockets, as well as to the conversion of a portion of the beamed energy into propellant mass, is discussed. The problems of electromagnetic power beaming are reviewed, and some potential solutions discussed. The possibility of utilizing iconospheres as a means of beaming power over astronomical distances is suggested.

From author's summary

2557. Rubin, S., General equation for rocket velocity, *ARS J.* **29,** 3, 219–220 (Tech. Notes), Mar. 1959.

The usual rocket-velocity equation is generalized to include very high exhaust velocity propulsion schemes such as ion rockets. This is done by permitting the exhaust velocities to be varied, independently of the fuel specific energy, and by considering the fuel and propellent to be different materials, with different masses and rates of consumption.

Calculations from the general equation for a single-stage rocket show that the conventional rocket motor yields the maximum rocket velocity for a given fuel, that is, the specific impulse of the propellant should be matched to that of the fuel.

For exhaust velocities greater than fuel kinetic velocity, the final rocket velocity is *inversely* proportional to the exhaust velocity.

S. Ostrach, USA

2558. Schuh, N. F., and Tallent, R. J., Solar-powered thermoelectric generator design considerations, *Elect. Engng.* **78,** 12, 1172–1176, Dec. 1959.

Some of the problems that will be encountered in designing a solar-powered space thermoelectric generator are outlined. A test model of a solar-powered generator is described.

From authors' summary

2559. Sutherland, G. S., Recent advances in space propulsion, *ARS J.* **29,** 10, 698–705, Oct. 1959.

This is a useful review of all the ideas that have been put forward, both simple and very far fetched, for possible methods of space propulsion. Among the methods which are now being seriously considered are free radicals trapped in a molecular matrix, nuclear propulsion with a gaseous cavity reactor, electrostatic and electromagnetic propulsion, solar propulsion using a sail technique or a power-collection technique, and thermonuclear propulsion. The basic obstacles to the various ideas are clearly stated.

M. W. Thring, England

Symposium of advanced propulsion, *Astronautics* **4,** 10, Oct. 1959.

2560. Rom, F. E., Advanced reactor concepts for nuclear propulsion, 20–22, 46–50.

2561. Grey, J., Gaseous-core nuclear rockets, 23–25, 110–112.

2562. Durham, F. P., Solid-core nuclear-rocket design, 26–27, 102–104.

2563. Bussard, R. W., Boundary conditions for nuclear propulsion, 28–29, 119–122.

2564. von Karman, T., Applications of magnetofluidmechanics, pp. 30 and 86.

2565. Camac, M., Plasma propulsion of spacecraft, 31–33, 113–115.

2566. Forrester, A. T., and Speiser, R. C., Cesium-ion propulsion, 34–35, 92–97.

2567. Stuhlinger, E., Photon rocket propulsion, p. 36, 69–78.

2568. Fulton, F. M., Canned liquid-rocket engines, 37–39, 105–106.

2569. Rutkowski, E. V., Variable-thrust rocket engines, 40–41, 80–81.

2570. Ordahl, D. D., Hybrid propulsion systems, 42–43, 84.

2571. Flourney, J. M., Free-radical fuels—a tough problem, p. 44, 106–107.

Magneto-fluid-dynamics

(See also Revs. 2556, 2559, 2564, 2565)

2572. Kapur, J. N., Superposability in magneto-hydrodynamics, *Appl. Sci. Res.* (*A*) **8,** 2/3, 198–208, 1959.

The concept of superposability of two hydromagnetic flows is defined, and it is shown that force-free fields and self-superposable fluid flows are particular cases. Chandrasekhar's equations for axially symmetric hydromagnetic flows have been extended to viscous fluids.

From author's summary by D. ter Haar, England

2573. McCune, J. E., and Sears, W. R., On the concepts of moving electric and magnetic fields in magnetohydrodynamics, *J. Aero/Space Sci.* **26**, 10, 674–675 (Readers' Forum), Oct. 1959.

Authors discuss recent papers in which magnetic field source is "fixed relative to fluid" or "fixed relative to plate" [Rossow, AMR **10**(1957), Rev. 4104; Bleviss, AMR **12**(1959), Rev. 3631, and Ong & Nicholls, *J. Aero/Space Sci.* **26**, 5, 313–314, May 1959]. Examination of field equations show the induced emf in magnetohydrodynamics is due to motion of conducting fluid particle relative to system in which observer measures the electric field. On this basis motion of the uniform magnetic field is irrelevant. Physical meaning is given to some solutions with "moving magnetic fields" by proper variation of an applied electric field. Authors stress importance of using correct transformations in future work.

Mary F. Romig, USA

2574. Covert, E. E., A microscopic analysis of magneto-gas-dynamics, Mass. Inst. Technol., Naval Supersonic Lab. TR 395, 42 pp., 1959.

The kinetic theory approach to magneto-gas-dynamics is discussed. The several methods of considering interactions, in which the long-range forces are of importance, are compared critically. In particular, the effects of the magnetic field on the particle interactions and their trajectories are shown to introduce anisotropies in magneto-gas-dynamics. The effects of these anisotropies are briefly discussed.

From author's summary

2575. Covert, E. E., and Kerney, K., A review of the literature of plasma physics, WADC TR-59-486 (Mass. Inst. Technol., Naval Supersonic Lab. TR 373), 176 pp., July 1959.

The level of development of plasma physics is discussed. It is found that the present theories account for the experimental effects if:

(1) the plasma is sufficiently dense so that the time between collisions is small compared to the time an atom stays in the excited state but is sufficiently rare so that the volume of the particles making up the plasma is very much smaller than the volume of plasma; (2) the potential energy between particles is the sum of the particles potential energy; (3) the excitations are sufficiently weak, or the duration of the event is sufficiently short, so that linearized theories are applicable.

The complexity of the basic equations allows the inference to be drawn that it is possible for interesting phenomena to exist which are not yet discovered, and that the known but unexplained phenomena are contained within these equations.

From authors' summary

2576. Sakuntala, M., Clotfelter, B. E., Edwards, W. B., and Fowler, R. G., Electromotive force in a highly ionized plasma moving across a magnetic field, *J. Appl. Phys.* **30**, 11, 1669–1671, Nov. 1959.

When a cloud of highly ionized gas flows across a magnetic field, an emf is produced in the gas which is proportional to the speed of flow. Oscillographic probe measurements have been carried out giving the flow speed as a function of position. By drawing currents from the probes the plasma resistance can be found at various distances from the plasma generator. The resistance is shown to be due to the motion of positive ions.

From authors' summary

2577. Blankfield, Judith, and McVittie, G. C., A method of solution of the equations of magnetohydrodynamics, *Arch. Rational Mech. Anal.* **2**, 5, 411–422, Feb. 1959.

Theory developed earlier [Blankfield and McVittie, *Arch. Rational Mech Anal* **2**, 1959] is applied to case of nonviscous infinitely conducting gas. Procedure depends on degenerating Einstein's equations of general relativity. Solutions are found in terms of indeterminate functions which are degenerate forms of the generalized potentials of relativity theory. A specific case of an infinite slab of gas is worked out to illustrate the method. An interesting paper.

S. H. Maslen, USA

2578. Liboff, R. L., Transport coefficients determined using the shielded Coulomb potential, *Physics of Fluids* **2**, 1, 40–46, Jan.-Feb. 1959.

The scattering integrals in the Chapman-Enskog expansion diverge for Coulomb interactions. Instead of using a cut-off at the Debye distance, author proposes a shielded Coulomb potential. Transport coefficients are calculated with this method and compared with the results of the Debye cut-off procedure. Both calculations lead to the same dominant logarithmic term. To the next order of accuracy, a difference of the order of 0.5% is found for the viscosity and a difference of the order of 2% is obtained for thermal conductivity.

H. G. Loos, USA

2579. Fraenkel, L. E., A shallow-liquid theory in magnetohydrodynamics, AFOSR TN 59-563 (Calif. Inst. Technol., Guggenheim Aero. Lab.; ASTIA AD 216 758), 74 pp., June 1959.

This is a report on the extension of nonlinear and linearized theories of shallow-water motion to the case of a conducting, inviscid liquid in the presence of a uniform, vertical, applied magnetic field. The magnetic Reynolds number based on a length L characterizing the horizontal extent of the flow pattern is assumed to be $0(1)$ and it is found necessary to restrict a dimensionless field strength parameter to a small value. For mercury this is found to imply field strengths around 3000 gauss if L is about 0.1 meter. The resulting equations apply to flows in which the depth is small compared to the wavelength of disturbances but the amplitude of disturbances may be of the order of the depth. These equations are not solved but are studied by means of characteristic variables. Shock waves (hydraulic jumps or bores) are also treated. The author gives the conservation laws for such discontinuities without detailed proofs; he finds that they are unchanged by the presence of the field. The accompanying energy equation is also stated without proof and is not completely understandable to the reviewer.

When the amplitude of disturbances is small the equations may be linearized; a form of the telegraph equation results. Solutions are given for both standing and traveling waves in a dish. There appears to be rapid damping, associated with the dissipation of of mechanical energy by Joule heating.

W. R. Sears, USA

2580. Freeman, N. C., On the flow past a sphere at hypersonic speed with a magnetic field, *J. Aero/Space Sci.* **26**, 10, 670–672 (Readers' Forum), Oct. 1959.

The constant-density solution to the hypersonic inviscid flow past a sphere obtained by Lighthill (1957) has been extended to the case of a sphere with a radial magnetic field in conducting fluid by Kemp (1958). This solution is, however, shown to be incorrect due to special assumptions for the functions concerned. The difficulty arises because the first approximation in some expansion procedure vanishes, causing a singular behavior in the higher-order terms. Author presents a theory where the approximations are uniformly valid.

W. Wuest, Germany

2581. Brandt, A. A., and Kurtmulaev, R. Kh., Investigation of fast ionization processes in the gas flow behind a shock wave, *Instruments and Experimental Techniques* no. 6, 808–811, Oct. 1959. (Translation of *Pribory i Tekhn. Eksper., USSR* no. 6, 94–97, Nov./Dec. 1958 by Instrument Society of America, Pittsburgh, Pa.)

A method is described for measuring the coefficient of thermal ionization of a gas which flows behind a shock wave propagating at a velocity of approximately 3 km/sec in a shock tube. The duration of the ionization process depends on the velocity of the shock wave, and is approximately 200 microseconds. The method which has been developed makes it possible to measure the ionization at a number of points (10–15) uniformly distributed along the path (accuracy approximately 10%); thus, it is possible to determine the duration of the ionization pulse and the slope of the wave fronts. The measurements are carried out by means of a cavity resonator which operates in the 10-cm region.

From authors' summary

2582. Tuck, J. L., Plasma jet piercing of magnetic fields and entropy trapping into a conservative system, *Phys. Rev. Letters* **3**, 7, 313–315, Oct. 1959.

Supported by some rough calculations from the theory of magnetic field-charged particle interactions, author proposes a new scheme for trapping and randomizing the energy of a jet of cold plasma entering a magnetic field. It is shown that the jet will inflate a balloon-shaped cavity through a "neck" in the field configuration. If the jet is turned off, the neck will contract and seal off the balloon. The method is somewhat analogous to the formation of a bubble around a solid penetrating a liquid surface and may present similar stability problems. The "picket fence" or cusped geometry fields are particularly well suited to this device. Author points out that if no further heating of the trapped plasma is desired and optimum temperatures for DT thermonuclear reactions are to be achieved, a 30-fold increase in presently available plasma jet velocities is required. Reviewer believes this to be an interesting new approach to the problem of hydromagnetic containment of high-temperature plasmas. P. Savic, Canada

2583. Hasimoto, H., Magnetohydrodynamic wave of finite amplitude at magnetic Prandtl number 1, *Physics of Fluids* **2**, 5, 575–576 (Research Notes), Sept./Oct. 1959.

Author shows that for an incompressible viscous conducting fluid the nonlinear terms disappear from the magnetohydrodynamics equations provided that (1) the sum of the hydrostatic pressure, magnetic pressure and the potential of the conservative body forces is constant, (2) the ratio of kinematic to magnetic viscosities (magnetic Prandtl number) equals unity, and (3) the velocity and magnetic field perturbations satisfy Walén's relation. It follows that a simple, solenoidal, dissipative wave of finite amplitude can exist. In the steady case the equation for the velocity perturbation is similar to those arising in the classical Oseen treatment of viscous flows. Consequently it admits of solutions with singularities in the finite domain and wakes parallel to the velocity vector compounded of the free-stream velocity and the Alfven wave velocity. The interesting possibility then exists that wakes may appear in front of obstacles responsible for the perturbations if the Alfven speed exceeds the free-stream speed [see also H. Hasimoto, *Physics of Fluids* **2**, 3, 337–338 (Research Notes), May–June, 1959]. J. F. Clarke, England

2584. Ingard, U., Simple examples of magnetomechanical wave motion, *J. Acoust. Soc. Amer.* **31**, 7, 1033–1034 (Letters to the Editor), July 1959.

The phase velocity on a periodic line consisting of coupled mass elements (coils) in a magnetic field is shown to be analogous to the phase velocity of a transverse Alfven wave in a conducting, incompressible fluid. As another example of the magnetomechanics of a simple "distributed" system, the motion of a conducting string in a magnetic field is discussed.

From author's summary

Aeroelasticity

(See also Rev. 2244)

2585. Wilts, C. H., Investigation of methods for computing flutter characteristics of supersonic delta wings and comparison with experimental data, NASA TN D-5, 65 pp., Aug. 1959.

This report contains flutter analyses of 45° and 60° delta wings carried out on the electric direct-analog computer. The wings considered are those of which wind-tunnel tests have been reported in the literature. The wing structure was represented by an electrical analog for a uniform plate. The aerodynamic forces, introduced in the analog by electronic transfer admittances, were obtained for a delta wing with a supersonic leading edge by means of simple strip theory or a more accurate box method, where the pressure at a given point depends on the motion of that point and all other points within the forward sweeping Mach cone. It is found that only the two lowest normal modes play a role. At low Mach numbers flutter was predicted with good accuracy, at Mach 3.0 there was a 10 to 20% difference between experimental and computed values of flutter speed. The computed values were in general unconservative. A possible explanation for this discrepancy is given. M. Botman, USA

2586. Shulman, Y., Vibration and flutter of cylindrical and conical shells, AFOSR TR 59-776 (Mass. Inst. Technol., Aeroelastic and Structures Research Lab. TR 74-2), 174 pp., June 1959.

Report represents major part of author's doctorate thesis at M.I.T. Chapter 1, Introduction, reviews role of plate and shell theories in present-day aeroelasticity developments. Chapter 2, Some developments in thin-shell theory, presents simplified general expressions which reduce to Donnell's equations for the case of a circular cylindrical shell. Similarity to shallow-shell theory is shown. Chapter 3, Vibrations of conical shells, applies shallow-shell theory, thin-shell theory, and the more exact Flügge shell theory to subject problem. Various approximate solutions are found, and an optimum method is indicated. Chapter 4, The general panel flutter problem, reviews this phenomenon, and discusses analytical methods for its solution. This discussion is applied in Chapter 5, Cylindrical shell flutter, and in Chapter 6, Conical shell flutter. It is shown that panel and shell flutter are basically the same. Numerical results, based on Galerkin's method, are given for the cylindrical and conical shell cases. Flutter speed and frequency are found to become minimum for a particular mode number (number of circumferential waves). Taper of the conical shell is found to increase its flutter speed. Chapter 7 summarizes major conclusions of report. Fifty-five references are given. J. C. Truman, USA

2587. Strack, S. L., and Holt, M., Supersonic panel flutter of a cylindrical shell of finite length, AFOSR TN 59-547 (Brown Univ., Div. Appl. Math.; ASTIA AD 216 693), 56 pp., May 1959.

Panel flutter equations for a finite length cylinder in supersonic flow are developed and solved. Quasi-steady linearized supersonic aerodynamic forces are based on the results presented in a previous paper by Holt [AFOSR TN 58-974]. Use of several possible elastic cylinder equations is discussed, and the equation of Gol'denveizer ["Teoriia Uprugikh Tonkikh Obolochek," Gos. Tekh. Lit., Moscow, 1953] is chosen for the analysis. This is a

fourth-order equation as opposed to the eighth-order equation of Donnell used in some previous analyses. The results are compared with other investigations and the general conclusion is reached that the use of more realistic aerodynamic terms leads to higher estimates of the critical flutter Mach number.

J. G. Eisley, USA

2588. Henry, C. J., Dugundji, J., and Ashley, H., Aeroelastic stability of lifting surfaces in high-density fluids, *J. Ship Res.* **2**, 4, 10–21, Mar. 1959.

Limited amount of flutter tests at low values of the structural to fluid mass ratio are reviewed. It appears that flutter instability is unlikely for the low mass ratios typical of underwater hydrodynamic operations, although divergence remains a possibility. A parametric study of the effect of the mass ratio, for a special example and following standard procedure, shows that flutter will become milder at the lower mass ratios and eventually ceases to occur. Much of the paper is designed to introduce conventional flutter analysis to naval architects. S.-F. Shen, USA

2589. Holt, M., Aerodynamic forces on a cylindrical shell in panel flutter, AFOSR TN 58–974 (Brown Univ., Div. Appl. Math.; ASTIA AD 205 598), 12 pp., Dec. 1958.

The aerodynamic forces resulting from the unsteady distortion of a circular cylinder of finite length, in a uniform supersonic stream, are determined. The problem is very similar to that of finding the steady flow past a quasi-cylindrical duct [which] has been solved by Randall [AMR **12**(1959), Rev. 1926] in terms of modified Bessell functions of the second kind.

The forces on the finite cylinder are compared with corresponding forces on an infinite cylinder, which have been used previously in cylindrical panel flutter analyses. In the case of infinite length, circumferential distortion introduces a constant factor into the expression for the surface pressure; .... on a cylinder of finite length, circumferential distortion causes the surface pressure to be damped in the axial direction. The effect of finite length of cylinder should therefore be to improve panel flutter characteristics. From author's summary by J. G. Eisley, USA

2590. Chu, W.-H., and Abramson, H. N., Effect of the free surface on the flutter of submerged hydrofoils, *J. Ship Res.* **3**, 1, 20–27, June 1959.

Authors investigate the lift and moment acting on an oscillating hydrofoil submerged near a free surface. The analysis is an extension of the classical unsteady thin-airfoil theory.

The mathematical formulation is derived from the method of images in reference to the surface. Authors assume that the potential of the local velocity can be considered as a sum of three potentials, viz: (a) the potential of the bound vortex; (b) the potential of the free vortex behind the hydrofoil; and (c) the potential of the vortex sheets in the image. The effect of the surface waves, considered small, is neglected.

A numerical example is used to compute the flutter of the hydrofoil. M. Strscheletsky, Germany

2591. Sirazetdinov, T. K., Vibrations of a wing of large aspect-ratio in a subsonic flow (in Russian), *Izv. Vysbcb. Uchebn. Zavedenii Aviats. Tekbn.* no. 1, 43–52, 1958; *Ref. Zh. Mekb.* no. 1, 1959, Rev. 174.

A method is given for determination of the circulation along the span of a vibrating wing of large aspect ratio in a subsonic flow. The problem is linearized and the generally accepted assumptions of the linear theory are made. The inductive taper of the flow of the wing is presented in the form of the sum of three items. The first item gives the quasistationary taper of the flow of a wing of finite span, the second takes into account the influence of the eddying "wake," while the third, the influence of the wing's section. An integral-differential equation is derived for a vibrating wing of large aspect ratio for vibrations of small frequencies; in order to obtain an approximate solution a method is indicated for combining it with a system of algebraical equations.

M. K. Fursov
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Aeronautics

(See also Revs. 2147, 2150, 2403, 2468, 2511, 2610)

2592. Herb, H., Design considerations on the reduction of aircraft take-off and landing distances (in German), Dtsch. Forschungsanstalt Luftfahrt Ber. 80, 68 pp., 1959.

Paper presents a review in the light of published data of the main factors controlling the take-off and landing distances of aircraft and draws attention to the design features which make for reduction of these distances. Propeller and jet-driven aircraft are considered, and some discussion is given of the use of boundary-layer control, circulation control, VTOL arrangements, reversed thrust and catapult braking. Paper contains nothing of research interest but it should be of interest to members of design teams.

A. D. Young, England

2593. Liberatore, E. K., A parameter for comparing ground effect vehicles, *Aero/Space Engng.* **18**, 10, 33–36, Oct. 1959.

Proposed here is a parameter for comparing the hovering performance of ground effect vehicles. This parameter is called the "Factor of Merit" and is defined as $M_F = [HW^{3/2}/(D_t^2 BHP_e)]$. Hovering performance theory shows it is applicable to the plenum chamber and annular jet configurations.

The parameter is compared with the "Figure of Merit" used with helicopter rotors, and its relation to efficiency is shown. Some values for ideal and actual "Factor of Merit" are also included.

From author's summary

2594. Riebe, J. M., Consideration of some aerodynamic characteristics during take-off and landing of jet airplanes, NASA TN D–19, 11 pp., Sept. 1959.

These considerations are limited to lift-drag relations and do not include such possible related factors as noise, heating, foreign-matter ingestion, or ability to obtain thrust reversal. Because of the absence of propeller-slipstream effects on wing lift, speed and attitude may require closer attention for jet transports than for propeller-driven transports. Jet transports, by the application of a lift-augmentation system, can have a lift-coefficient response with power on similar to that which has provided an operational margin for propeller-driven transports.

From author's summary

2595. McKay, J. M., Measurements of ground-reaction forces and vertical accelerations at the center of gravity of a transport airplane taxiing over obstacles, NASA TN D–22, 27 pp., Sept. 1959.

Results are presented of the effects of ground speed and obstacle width on the vertical and rearward drag ground-reaction forces, the vertical acceleration at the center of gravity of the airplane, the shock-strut displacement, and the dynamic response of the upper mass of the airplane structure. The obstacles were 3.0 inches in height and 1 and 4 feet in width, and the investigation covered a range of ground speeds from 12 to 86 knots.

From author's summary

2596. Ayers, E. F., and Doran, P. D., A practical approach to turbojet engine management and trouble shooting in flight, *Aero/Space Engng.* **18**, 10, 40–44, Oct. 1959.

Astronautics

(See also Revs. 2153, 2272, 2297, 2415, 2422, 2450, 2462, 2511, 2557, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571)

2597. Sterne, T. E., Effect of the rotation of a planetary atmosphere upon the orbit of a close satellite, *ARS J.* **29,** 10, 777–782, Oct. 1959.

"The rotation of a planetary atmosphere along with the planet changes all the orbital elements of a close satellite. Expressions are derived for such variations." Diminution of the orbital period, decrease of eccentricity, decrease in the inclination, and changes of other parameters are discussed. Comparison of observation with theory of the decrease of inclination shows good agreement for satellite 1957 Beta-1 and acceptable agreement for 1958 Beta 2. "Equations are derived to permit the inference of atmospheric density from the mass and area of a satellite and from its observed orbital behavior..." In addition, reviewer believes the material of this article to be useful for the computation of flight paths of low-thrust vehicles starting from earth-satellite orbits.

The article is largely mathematical, but it may be easily understood by anyone having a background in engineering or physical science. I. J. Eberstein, USA

2598. Bamford, H. E., Jr., The orbital plane interpreter, *Aero/Space Engng.* **18,** 10, 37–39, Oct. 1959.

An instrument is proposed which would present a geometric interpretation of those elements of a spacecraft's orbit which define its path and position in a given plane. Actual and required orbits can be simultaneously indicated. Numerical values of all six elements of one orbit are also indicated.

The instrument may be driven automatically, semiautomatically, or manually. In any case its purpose is to assist the crew in such control problems as orbital rendezvous by assuming some of the burden of interpreting and planning.

From author's summary

2599. Munick, H., Determination of elements of an elliptic orbit from the orbital velocity vector, *ARS J.* **29,** 2, p. 150 (Tech. Notes), Feb. 1959.

2600. Lenzi, E., Calculation of satellite orbits (in Italian), *Riv. Aero.* **35,** 2, 233–258, Feb. 1959.

2601. Long, R. S., Escape from a circular orbit with finite velocity at infinity (in English), *Astronaut. Acta* **5,** 3/4, 159–162, 1959.

The problem of programming the thrust direction of a rocket in order to escape from a circular orbit with minimum expenditure of fuel is considered on the assumptions that the rocket thrust per unit mass is large and constant, and that the velocity to be reached at infinity is specified. The use of transverse thrust and of tangential thrust is also considered. It is found that tangential thrust gives a close approximation to the more complex optimal thrust program. From author's summary

2602. Robey, D. H., Cold re-entry of space vehicles at meteor speeds (in English), *Astronaut. Acta* **5,** 3/4, 224–240, 1959.

The possibility of using frozen water as a protective covering for space vehicles, re-entering at parabolic velocity, has been investigated. A series of curves for solid ice spheres showing the thermal and dynamical re-entry characteristics is presented. The results are very encouraging, especially for the cold return of instrumentation where steep re-entries and high decelerations can be tolerated. More gentle re-entries require thicker ice layers but the high-temperature problem is avoided.

The recovery of a circumlunar probe in undamaged condition (because of heating) appears quite feasible.

From author's summary

2603. Thuring, B., Two special trajectories of capture by the moon in a space travel around earth and moon (in German), *Astronaut. Acta* **5,** 3/4, 241–250, 1959.

By means of the electronic computer Univac-Factronic (Frankfort/Main) two trajectories of the three-body problem have been calculated. These are in the Earth-Moon plane and are representative of "bottle neck" and "capture trajectories." The Lagrangian libration points L_1 and L_2 are passed through a narrow pass of the limit curves according to Hill; once from the geo-lunar interior space, the other time from the geo-lunar exterior space. Both of them lead to a "capture" by the Moon.

The trajectories are characterized by a *frequent* driving round the Earth, or around the entire Earth-Moon system before passing through the narrow pass at L_1 or L_2, respectively.

Perturbations caused by the Sun have not been taken into consideration. From author's summary

2604. Kirmser, P. G., and Wakabayashi, I., Triangulation—a precise method for satellite tracking, *J. Franklin Inst.* **268,** 5, 337–351, Nov. 1959.

A scheme is presented for the triangulation of satellite positions by means of two observing stations, each providing the two angular coordinates of the apparent positions of a satellite as seen from each of the observing stations at a given time instant. It is pointed out correctly that this method would be superior to "stadia" and Doppler shift method in that it can be used to determine the paths of non-free-fall type objects. Furthermore, this method may be used with a single observing station through the application of the pseudo-triangulation technique, whereby the observations taken at different times from one observing station are used for triangulation in conjunction with known data on the precession angle of the satellite.

Reviewer would like to point out that while this method may be useful for a single satellite object or a small number of satellites, it appears questionable whether it can be developed into a tracking system with a sufficiently large handling capability. For high traffic density problems, immediate determination of orbital parameters is believed to be mandatory. These two factors appear as the basic deficiencies of the method presented, although they are not the primary objectives of the paper.

C. C. Wan, USA

2605. Augenstein, B. W., Dynamic problems associated with satellite orbit control, *ASME Trans.* **81B** (*J. Engng. Industry*), 4, 281–288, Nov. 1959.

Author discusses analytically the general problem of changing, by means of impulsive forces, the orbital parameters of a satellite moving in a conical orbit under a central field. Classical analyses are available for small perturbations of the orbit, such as would be needed to correct for initial errors of guidance or propulsion, but for many cases of practical importance such an analysis is inadequate. Author's approach is to use exact solutions for conical motion with perfectly general initial conditions. Cumbersome analysis is avoided by using graphical solution based on generalized charts given in paper; higher accuracy could be obtained by computer solution of general equations. The following types of problem can be solved: (a) With given initial conditions, obtain the parameters of the orbit (Newton's planar problem); (b) orbit trimming; (c) maneuvering between arbitrary orbits without time restraint; (d) collision of bodies moving in arbitrary conical orbits by impulses applied to one; (e) rendezvous of bodies in

arbitrary conical orbits by impulses applied to both. Worked solutions to examples of (a), (d) (noncoplanar orbits) and (e) (coplanar orbits) are given. In each case the propellant consumption to produce the necessary impulse is found and is shown to increase very rapidly as given time to rendezvous is decreased. Method is applicable to transfers between planetary orbits.

R. H. Macmillan, Wales

2606. Miele, A., and Coppellari, J. O., Jr., Topics in dynamic programming for rockets (in English), *Z. Flugwiss.* **7,** 1, 14–21, Jan. 1959.

Miscellaneous topics associated with the programming of optimum trajectories for rocket-powered vehicles are investigated. Particular attention is devoted to these problems:

(A) Programming of the thrust direction and of the thrust modulus with aerodynamic forces included: it is shown that the optimum path includes zero-thrust subarcs, full-thrust subarcs, and variable-thrust subarcs. The conditions to be fulfilled so that the Legendre-Clebsch and Weierstrass criteria be satisfied are indicated.

(B) Programming of the thrust direction and of the thrust modulus in vacuum flight: it is shown that—at least for some particular types of boundary-value problems—no variable-thrust subarc may exist; the optimum trajectory includes only zero-thrust subarcs and full-thrust subarcs.

(C) Maximum range in vacuum flight for the case where both the initial and final path inclinations are free and the velocity modulus at final point is also free: it is shown that the absolute inclination of the vector thrust is a constant; the initial velocity is parallel to the vector thrust; the final velocity is perpendicular to the vector thrust. Assuming that the initial velocity is other than zero, a general solution is obtained. This solution includes, as a particular case, previous work done by Lawden and R. R. Newton for the case where the rocket is initially at rest.

From authors' summary

2607. Scala, S. M., Thermal protection of a re-entry satellite, *ARS J.* **29,** 9, 670–672 (Tech. Notes), Sept. 1959; **30,** 1, p. 132 (Tech. Comments), Jan. 1960.

Three methods for protection, heat sink, transpiration and ablation are discussed. Results are given for re-entry angle 92.5° from vertical, initial velocity 24,000 fps, initial altitude of 900,000 ft and $W/C_DA = 50$, 100 and 200. It would be interesting to see results for larger values of W/C_DA.

Curves showing temperature as function of distance and time for a one-dimensional heat sink are given. However the properties of the heat sink material (heat capacity, thermal conductivity) are not stated. After a very brief outline of theory the mass required for maintaining a fixed wall temperature using transpiration cooling is plotted. Finally curves of mass loss due to ablation are discussed.

In the addendum, mass transfer is plotted as a function of W/C_DA for ablation of teflon, reinforced plastic, quartz and graphite. In addition, mass transfer for transpiration cooling is shown.

This paper accomplishes two things: First, the results of calculations for three different systems are provided for comparison; and second, the paper serves as a guide to other papers. For the reader wanting only a qualitative understanding of the relative merits of the cooling methods, this paper is adequate. To extend the results to other initial conditions it would be necessary to consult the references. A. Fuhs, USA

2608. Katzen, E. D., Terminal phase of satellite entry into the earth's atmosphere, *ARS J.* **29,** 2, 147–148 (Tech. Notes), Feb. 1959.

2609. Molmud, P., Frictional electricity in missile systems, *ARS J.* **29,** 1, 73–75 (Tech. Notes), Jan. 1959.

2610. Welmers, E. T., Space applications for rocket vehicles, *Aero/Space Engng.* **18,** 9, 38–42, Sept. 1959.

After an historical introduction, author develops requirements for a manned vehicle capable of repeated landings and take-offs, designed and equipped to vary the orbital plane, the orbital altitude, and the attitude. A manned space glider is suggested with reaction controls for attitude and thrust orientation; adequate main thrust for safe launch, boost, and orbital changes; proper environment for the crew; and aerodynamic control for repeated re-entry and landing maneuvers. Such vehicle is said to be feasible with our technology of today. H. P. Liepman, USA

2611. Laitone, E. V., Effect of acceleration on the longitudinal dynamic stability of a missile, *ARS J.* **29,** 2, 137–139 (Tech. Notes), Feb. 1959.

The effect of high rates of acceleration or deceleration is introduced into the linearized equations of motion predicting the behavior of the short period longitudinal oscillations of a nonrolling missile having a longitudinal plane of symmetry and trimmed to fly at a nearly zero lift trajectory.

From author's summary

2612. Sohn, R. L., Rapid method for computing high altitude gravity turns, *ARS J.* **29,** 2, 139–141 (Tech. Notes), Feb. 1959.

This note describes a method for computing powered flight trajectories of a missile at high altitude in near horizontal flight. The method gives closed form solutions to the velocity, flight path angle and altitude changes during powered flight under the following assumptions: No drag, near horizontal flight ($\beta \pm 30$ deg from horizontal), spherical Earth, general initial conditions, and gravity turn (α = zero deg).

The method is best used to compute the performance of final power stages where booster data up through the atmosphere is already available. From author's summary

2613. Boyars, C., Surveillance of solid propellant rockets, *ARS J.* **29,** 2, 148–150 (Tech. Notes), Feb. 1959.

2614. Flowers, J. V., Automation of prelaunch tests of missiles and space vehicles, ASME Aviation Conf., Los Angeles, Calif., Mar. 1959. Pap. 59-AV-42, 20 pp.

Ballistics, Explosions

(See also Revs. 2381, 2382, 2384, 2391, 2394, 2469, 2538, 2539)

2615. Kapur, J. N., Solution of the equations of internal ballistics for the pressure-index law of burning, *J. Sci. Engng. Res., India* **3,** 1, 1–6, Jan. 1959.

The equations describing acceleration of a projectile in a gun barrel are solved in a series of powers of $(1 - n)$, where n is the pressure exponent of burning rate. The results are good for n between 0.9 and 1.0 and fair for n between 0.8 and 0.9. Effects of n on pressure, position of maximum pressure, shot travel, and muzzle velocity are stated. R. Friedman, USA

2616. Holt, M., and Strack, S. L., Refraction of shock waves in a non-uniform ocean, Brown Univ., Div. Appl. Math., TR 18 (Contract Nonr-562(07) (NR-062-179)), 15 pp., May 1959.

An ocean with a thin layer of water at constant temperature overlying a region of linear decreasing temperature is considered. If an explosion occurs in the lower region the acoustic ray theory predicts a shadow zone just below the discontinuity. Measurements show that the shock wave penetrates the shadow zone but the pressure builds up slowly to a maximum. In order to settle this anomally authors apply method of Griffith, [*J. Aero. Sci.* **23,**

p. 169] to a shock wave moving into a region of transverse temperature gradient. Disturbed field behind refracted shock is similar to observations in shadow zone.

W. D. Baines, Canada

2617. Romanenko, E. V., Experimental investigation of the propagation of finite-amplitude spherical waves, *Soviet Phys.-Acoustics* **5,** 1, 100–104, Aug. 1959. (Translation of *Akust. Zh.* **5,** 1, 101–106, Jan./Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

The propagation of spherically diverging waves of finite amplitude is investigated in the case of pulse radiation at a frequency of 1.15 Mc and a pressure amplitude at the radiator surface up to 26 atmos. The results of the experiment are compared with theory and a satisfactory agreement is obtained. The construction designs of the ultrasonic radiator and pickups used in the experiments are described. A method is described for determining the frequency characteristics of pickups over a wide frequency range; this is based on the change in the finite-amplitude waveform during its propagation. From author's summary

2618. Antsiferov, V. S., Automodel problem of the penetration of a solid body into the ground, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **22,** 6, 1231–1239, 1958. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Problems of penetration of a solid body into the ground (or about underground explosions) are solved when certain assumptions as to the properties of the investigated medium are made. In this work, such a schematic medium is an ideal (nonviscous) and barotropic gas. The body in motion here is a circular cone with a constant velocity of penetration (with the angle of attack = 0).

T. Riabokin, USA

2619. Summers, J. L., Investigation of high-speed impact: regions of impact and impact at oblique angles, NASA TN D-94, 18 pp., Oct. 1959.

Small metal spheres of widely varying densities were fired into copper and lead targets at velocities to 11,000 fps. Analysis of the high-speed results of the investigation indicates that the target penetration and cavity volume can be correlated as functions of the ratio of projectile to target density and of the ratio of impact velocity to speed of sound in target material. Impact for which the correlation equations apply is described as occurring in the fluid-impact region. This type of impact as well as other types is discussed. Penetration for impact at oblique angles is correlated with that for normal impact on the assumption that the component of velocity parallel to the target surface does not contribute to target penetration. From author's summary

2620. Buchmann, E., The response of simple heavy steel targets to underbottom explosion attack, David W. Taylor Mod. Basin Rep. 1137, 13 pp., May 1958.

Underwater explosion tests were conducted against simple heavy steel targets either at or below the water surface. These tests extend the investigation of simple floating targets to targets considerably heavier than the water they displace. The response of the targets yields an insight into the forces developed on ships by the accelerated water flow accompanying gas-bubble pulsation.

The velocity of the targets was recorded as a function of time. The initial peak velocity and the final maximum velocity were correlated with explosion parameters such as the impulse from the initial part of the shock wave and the maximum positive impulse during the bubble expansion. If appropriate allowances are made for the effects of acoustical impedance, mass, and entrained mass of the targets, the observed velocities agree with those predicted by theory. The final maximum velocity indicates the momentum of the target and its entrained mass equals the momentum of the displaced water and its entrained mass.

From author's summary

Acoustics

(See also Revs. 2240, 2354, 2448)

Book—2621. Herforth, L., and Winter, H. M., Ultrasonics [Ultraschall], Leipzig, B. G. Teubner Verlagsgesellschaft, 1958, vii + 235 pp. + 50 figs. DM 12.

The title of this little book is somewhat pretentious and authors seem to have felt this themselves. In the foreword they state that "Brief textbook on ultrasonics" might be a better title. Reviewer feels that even this title does not describe the contents of the book well enough for two reasons. First, laws and equations are given without derivations, which is necessary at least to some extent in a textbook, and second, too much emphasis is placed on the applications of ultrasonics on biology and medicine as the following table of contents shows:

A. Basic Laws and Methods: I. Generation of ultrasonic waves, 26 pages; II. The ultrasonic field and its effects, 14 pages; III. Detection and measuring of ultrasonics, 17 pages.

B. Applications of ultrasonics: IV. Ultrasonics in physics, technology and industry, 70 pages; V. Ultrasonics in biology, 35 pages; VI. Ultrasonics in medicine, 32 pages. A very adequate list of 562 references and 52 photographs of ultrasonic measuring techniques and equipment conclude the book.

In spite of its obvious unbalance the book is well written and arranged. All basic equations are printed in heavy letters for quick reference. Sixty-five figures in the text are well selected for better readability. In the "Applications" a considerable number of cases have been described; however, little effort has been made to critically separate the more promising applications from the questionable ones.

In conclusion, the book should be of considerable interest to biologists and medical scholars who want to familiarize themselves with the potentialities of ultrasonics in their fields. They will find the part on basic laws and methods adequate.

For the engineer the book contains too large a part which deals with items of which he does not even know the terminology. The book is not suitable for college students except for postgraduate students, particularly in the fields of biology and medicine.

H. J. Ramm, USA

2622. Dianov, D. B., Ultrasonic radiation through plane-parallel layers, *Soviet Phys.-Acoustics* **5,** 1, 30–35, Aug. 1959. (Translation of *Akust. Zh.* **5,** 1, 31–38, Jan./Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

The radiation of a piezoquartz vibrator through plane-parallel layers is calculated. The equations are discussed for different cases. For one layer with a thickness of $\lambda/4$ and a low acoustic impedance z_2 between the vibrator (thickness $\lambda/2$) and the medium with the impedance z_3, the maximum intensity of the radiation rises about the factor $(z_3/z_2)^2$. Discussion of the frequency characteristics is included. Several layers between the quartz-plate and the medium also lead, under certain conditions, to an increase in radiation intensity. Experiments on the frequency characteristics confirm these theoretical results. Experimental details are not given. O. E. Ruediger, Germany

2623. Corcos, G. M., Some effects of sound-reduction devices on a turbulent jet, *J. Aero/Space Sci.* **26,** 11, 717–722, 730, Nov. 1959.

An explanation is given of how ejectors, corrugated nozzles, and multiple nozzles modify the turbulent mixing of a jet so as to generate less aerodynamic noise. Simple analytic and dimensional

considerations lead to the conclusion that the noise reduction is due primarily to a decrease in turbulence levels in the mixing region. It is suggested that this is accomplished by accelerating the ambient air through a longitudinal pressure gradient before mixing it with the jet. Thus a sheath of flowing air decreases the lateral jump in the mean axial velocity which is responsible for the turbulence level in the mixing region. An experiment at low speed with an ejector and a corrugated nozzle is reported. Mean velocity profiles and turbulent surveys were obtained. The results are in good agreement with expectations and provide strong support for the hypothesis. R. C. Binder, USA

2624. Ingard, U., and Maling, G. C., Jr., Noise generated by two interacting air jets, *J. Acoust. Soc. Amer.* **31,** 7, 1031–1033 (Letters to the Editor), July 1959.

It has been observed that the excess noise generated as a result of the interaction or mixing of two small air jets is considerably greater than the noise produced by the individual jets. The "interaction noise" produced by jets that lie in the same plane has been measured for jet intersection angles between 0 and 180°. Similar measurements have been made as a function of jet separation by using two jets that intersect at a 90° angle but do not lie in the same plane. From authors' summary

2625. Ingard, U., Influence of fluid motion past a plane boundary on sound reflection, absorption, and transmission, *J. Acoust. Soc. Amer.* **31,** 7, 1035–1036 (Letters to the Editor), July 1959.

It is shown that the effect of fluid motion past a plane boundary on the reflection and absorption of sound is equivalent to an increase of the normal acoustic impedance of the boundary by a factor $(1 + M \sin\phi)$, where ϕ is the angle of incidence of the sound wave, and M is the Mach number of the flow velocity component in the incidence-reflection plane of the wave. Similarly, the acoustic energy flux perpendicular to the boundary and the flow is shown to be increased by the same factor. Reflection and transmission coefficients of a thin solid interface between a fluid in motion and one at rest are given. Furthermore, some comments on the problem of transmission in ducts are given. For propagation between two plane parallel boundaries with the same acoustic admittance, we find, for sufficiently small values of the admittance, that the sound pressure attenuation constant of the fundamental mode is modified approximately by the factors $(1 + M)^{-2}$ and $(1 - M)^{-2}$ for downstream and upstream propagation, where M is the flow Mach number. From author's summary

2626. Heins, A. E., and MacCamy, R. C., On the scattering of waves by a disk, AFOSR TN 59-721 (Carnegie Inst. Technol., Dept. Math. TR 29), 20 pp., June 1959.

A function $U(r, \theta, z)$, periodic in θ, is sought which satisfies $\nabla^2 U + k^2 U = 0$ away from the unit disk, vanishes on the disk, and satisfies the radiation condition and which is not a solution in spheroidal harmonics. The problem reduces to solving the integral equation

$$U^{(i)}(r, \theta, 0) + \frac{1}{4\pi} \int_0^1 \int_0^{2\pi} f(\rho, \phi) \frac{e^{ikR}}{R} \rho d\rho d\phi = 0 \qquad (z = 0, r < 1)$$

where $U^{(i)}$ is the incident wave and f is the discontinuity of U_z on the disk. For $k = 0$, Copson [*Proc. Edinburgh Math. Soc.* **3,** 14–19, 1947] expanded all quantities in Fourier series in θ and carried out the angular integrations to obtain simpler, soluble integral equations. Jones [*Comm. Pure Appl. Math.* **9,** 713–746, 1956] extended Copson's method to axially symmetric problems for arbitrary k. The authors simplify Jones' method and indicate its extension to the general case. The leading Fourier coefficients of f are computed when $U^{(i)}$ is a plane wave of arbitrary angle of incidence. N. D. Kazarinoff, USA

2627. Malyuzhinets, G. D., Sound scattering by nonuniformities in a layer of discontinuity in the sea, *Soviet Phys.-Acoustics* **5,** 1, 68–74, Aug. 1959. (Translation of *Akust. Zh.*, **5,** 1, 70–77, Jan./Mar. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

It is assumed that the velocity of sound in unbounded fluid changes from one constant value to another through a thin transition layer which varies slowly with time (for instance because of the presence of internal gravity waves in the fluid). A time-periodic source of sound is placed near the transition region. An expression is written down for the variation of pressure near the source due to the quasi-steady variation of the interface. This pressure is made up of contributions from all parts of the transition layer; it is found that the contributions have a simple form if they come from distances so great that the wave amplitude is small compared with the size of the first Fresnel zone. This result is applied to the calculation of sound intensity when the autocorrelation function of the motion of the interface is assumed to have a certain form, and an expression is given for the scattering coefficient. F. Ursell, England

2628. Buchman, A. S., Particle suspension technique for measuring scattered sound energy, *J. Acoust. Soc. Amer.* **30,** 10, p. 985 (Letters to the Editor), Oct. 1958.

In order to measure the ultrasonic energy scattered by small particles, a gel is used to imbed these particles. This technique offers an advantage over encapsulation in waxes or plastics from the viewpoint of attenuation and air bubble content. It also suppresses parasitic signals usually involved when using cemented thin fibers or other similar supporting mechanism. The gel solution is placed in a canister, suspended at the intersection of the transmitted and reflected beams. The canister being rotated around a vertical axis, the measurement of the scattered energy is the measure of eccentricity between particle and rotation axis. A standard target, a large diameter sphere, is used for calibration purposes. G. E. Jarlan, Canada

2629. Vovk, A. E., Pasternak, R. N., and Tyntekin, V. V., Experimental investigation of the wave properties of a medium with cylindrical channels (in Russian), *Akust. Zh.* **4,** 1, 24–32, 1958; *Ref. Zh. Mekh* no. 11, 1958, Rev. 13044.

The wave properties were experimentally investigated of a medium having the features of rubberlike materials and with cylindrical channels in it. A method is given for the calculation of the complex wave number by the measured magnitude of the complex impedance of a sample of such a medium. Results are furnished for the experiment for various radius dimensions of the channels. A comparison is made between the experimental results and the theoretical deductions. From authors' summary

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Micromeritics

(See also Rev. 2519)

2630. Rottner, J., A formula for bed-load transportation (in English), *Houille Blanche* **14,** 3, 301–307, May/June 1959.

The bed-load movement of a natural waterway depends not only on universal flow factors such as the slope, discharge, etc., but also on elusive local conditions which vary from time to time and from place to place. A bed-load formula should therefore be based in the first place on laboratory flume tests. A publication on the subject by J. W. Johnson ("Laboratory investigations on bed-load transportation and bed roughness") gives some 2500 experimental results in handy form for research on the subject. These results are not only abundant but also diversified and a formula derived

from them can be regarded as having a solid, critically sound backing.

A formula is in fact proposed, giving the bed-load discharge as a function of the flow parameters. A chart helps practical use. Subsequently the variation of the mean velocity of flow of water accompanying the bed-load transportation is examined and the results graphed on a chart which is of wider application than the former one. This enables the solid flow and the mean water velocity to be found from the slope, the flow depth and the grain size.

From author's summary

2631. Korotaev, Yu. P., Equation for the vertical motions of particles in linear and quadratic regimes of resistance (in Russian), *Trudi Vses. N.-i Prirodn. Gazov.* no. 2 (10), 78–82, 1958; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 595.

This is an investigation of the equation of motion of a heavy particle in a vertical flow of gas while taking account of the resistance in the form of the sum of two terms: linear and quadratic. In the case of a steady motion formulas are obtained for the velocity of particles of various sizes relative to the gas, which are suitable, according to the author's views, for the linear and quadratic regimes. The solution of the equation for an unsteady motion of a particle relative to a uniformly moving gas results, via some obviously justifiable conditions, in a formula expressing in a general form the damping of the velocity of the particles with time.

B. A. Fidman

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2632. Yalin, S., On the mechanics of solid transport (in French), *Houille Blanche* **13,** 6, 607–618, Nov. 1958.

With an impressive array of nomenclature, author shows that the Meyer-Peter formula for bed-load transport can be obtained from generally accepted concepts if the proper assumption is made for the number of particles taking part in the motion at any time as function of the flow. He derives the length of the saltation length following Bagnold but without referring to him. No mention is made of the effect of suspension, of small grain sizes or of mixtures. No numerical values of constants are given. No experiments are cited.

H. A. Einstein, USA

2633. Gillespie, T., and Gunter, A. W., The drag on spheres and cylinders in a stream of dust-laden air, *ASME Trans.* **81**E (*J. Appl. Mech.*), 4, 584–586, Dec. 1959.

A system has been developed for measuring the drag on small spheres and cylinders in a stream of dust-laden air. The drag was found to be proportional to the kinetic energy of the air plus the kinetic energy of the dust, and to be independent of particle size for particles having diameters in the range of 50 to 400μ. The well-known drag-coefficient versus Reynolds-number plots are the same for dust-free and dust-laden air provided the drag coefficient is calculated using the density of the two-phase system and the Reynolds numbers are calculated using the density of air alone. This suggests that the dust has little effect on the flow pattern. The results indicate that an instrument utilizing the drag principle to measure dust concentration could be developed.

From authors' summary

2634. Rose, H. E., and Tanaka, T., Rate of discharge of granular materials from bins and hoppers, *Engineer, Lond.* **208,** 5413, 465–469, Oct. 1959.

The rate of discharge of granular materials from storage bins and hoppers, through a circular aperture, has been investigated by the authors, using small-scale models and, by means of a simple correlation curve, the results have been extended to cover the case of noncircular apertures. It is considered that the equation deduced will allow the calculation of the rate of discharge of most materials from hoppers and bins of normal type, with an accuracy sufficient for most practical purposes.

From authors' summary

2635. Fischer, J., Pneumatic conveyers, ASME Semiann. Meet., St. Louis, Mo., June 1959. Pap. 59-SA-29, 3 pp.

2636. Barre, H. J., Flow of bulk granular materials, ASME Semiann. Meet., St. Louis, Mo., June 1959. Pap. 59-SA-45, 4 pp.

2637. Mukminova, A. G., Laboratory measurements on the transport of sand and dust in a tube (in Russian), *Trudi Sridneaz. In-ta* **11,** 58, 77–80, 1954; *Ref. Zh. Mekh.* no. 10, 1958, Rev. 11313.

Results are given for the observations made on the movement of sand in an aerodynamic tube with smooth and rough surfaces. The experiments were carried out with dry and moistened sand of different particle fractions with flow velocities in the tube of up to 9 m/sec.

L. M. Lebin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2638. Fatt, I., The Biot-Willis elastic coefficients for a sandstone, *ASME Trans.* **81**E (*J. Appl. Mech.*) 2, 296–297 (Brief Notes), June 1959.

2639. Surkov, V., Zolotin, Yu., and Limantov, G., Study of a flow of uniform liquid in the interplate spaces of a separator (in Russian), *Molochn. Prom-sti* no. 5, 35–38, 1957; *Ref. Zh. Mekh.* no. 10, 1958, Rev. 11112.

In order to improve existing knowledge of the mechanism of the process an investigation is carried out of a flow as described in the title. A description is given of the experimental apparatus used, including a separator with a capacity of 100 l/hr, a mechanical stroboscope with a powerful source of light and with a cine- or photographic outfit. For the experiments the drum of the separator consisted of a transparent material (organic glass), and to ensure complete synchronization the rotation of the drum and the disk of the latter was rigidly connected to the separator driving gear. Visual observations of the flow of liquid in the interplate spaces of the separator were made with different rates of rotation of the drum, varying outputs of the liquid and different spacings between the plates. As an outcome of the experiment the surface of a plate wetted by the liquid constituted 40% of its total surface when the separator was working normally and when the motion of the drum was steady. Thus, the motion of the liquid between the plates follows determined sectors in conjunction with which it should be noted that the actual velocity of motion of the liquid in the direction of the generatrix of the plate differs from the calculated, determined by the equation of output.

A. S. Ginevskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2640. Glover, R. E., and Daum, C. R., Behavior of dissolved and suspended materials in flowing streams, Proceedings of the Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16–18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 133–142.

The abilities of flowing streams of clear water to disperse dissolved materials was investigated by analytical and experimental treatment. Tests were made in two flumes, one 75, the other 400 feet long, with dissolved table salt as tracer element. Concentration at various points and times was recorded by measuring the electrical conductivity. Electrodes were connected with an oscil-

lograph for recording. Full-scale tests were made in a river with an unnamed nuclear isotope as tracer material. Longitudinal and lateral dispersion was investigated but no test results are given in the paper. Two equations for longitudinal dispersion, not deduced in paper, are given, but no correlation is made with test results. Authors conclude tests indicate that dispersion is a diffusion process and that density currents are easily formed. Suspended materials, mentioned in title, seem not to have been tested.

G. Selin, Sweden

2641. Vereshchagin, L. F., Semerchan, A. A., and Sekoyan, S. S., On the problem of the breakup of high-speed jets of water, *Soviet Phys.-Tech. Phys.* **4,** 1, 38-42, July 1959. (Translation of *Zh. Tekh. Fiz.* **29,** 1, 45-51, Jan. 1959 by American Institute of Physics, New York, N. Y.)

Porous Media

2642. Houpeurt, A., Analytical solution of flow of fluids in porous media possessing variable characteristics (in French), *Rev. Inst. Fr. Petrole et Ann. Comb. Liquid* **14,** 4/5, 549-559, Apr./May 1959.

Author considers the unsteady flow of a liquid of constant viscosity through porous media with variable porosity ω and permeability k. The temperature is assumed constant, and the density is assumed to depend on the pressure exponentially in the equation of state. Gravity is neglected, and only parallel flows and purely radial flows are considered, so that only one space variable is involved. The resulting equation can either be solved by assuming the unknown function to be a sum of a space function and a time function or by the ordinary method of separation of variables. The first method has very limited applications, and the second involves the solution of a second-order differential equation, with the space variable as the independent variable. Author's main contribution is the specification of a general relationship between ω and k which, if satisfied, leads to the integration of the equation in terms of known functions defined by familiar second-order differential equations.

Since ω and k are in general given *a priori*, and the satisfaction of the required relationship involves finding a transformation function $u(x)$ by solving a third-order nonlinear equation, author concludes that it is better to resort to computing machines. Since the limitation of the variations of ω and k to those with only one space variable is so severe that the results are only of limited interest, the reviewer wonders if machine calculations are really justified.

C.-S. Yih, England

2643. Scheidegger, A. E., On the theory of flow of underground fluids in compressible strata, *Canad. J. Phys.* **37,** 276-284, 1959.

It is shown that, in general, the motion of a fluid cannot be separated from that of the medium. This leads to a very complex problem of consolidation. However, considerable simplification can be made in applications to the flow of underground fluids. In that case, the general geometry of the consolidation can be predicted since the latter can take place in the vertical direction only. Furthermore, in many cases it is possible to neglect the volume compressibility of the porous matrix.

Two cases have been considered: that of local isotropy of stress and permeability and that of local anisotropy of these two quantities. The basic differential flow equation for the two cases is deduced.

From author's summary by F. C. De Nie, Holland

Book—2644. Benetin, J., Ground water flow [Pohyb vody v zemine], Bratislava, Vydavatel'stvo Slovenskej Akademie Vied, 1958, 215 pp. Kcs 16.60 (Paperbound)

Book contains the physical backgrounds of water movement in the soil, gravitational flow, capillary flow, filtration phenomena, water seepage in soils. Some practical applications and experimental methods are presented. Short summaries in Russian and in German conclude the book. Bibliography contains 97 entries, among them 44 Russian, 16 Czech, 14 German, 8 Slovak, 12 English (10 in Russian translation). The book is a survey of contemporary knowledge in ground water flow in Eastern Europe; it is well edited and illustrated.

S. Kolupaila, USA

2645. Klenov, V. B., Thermal modelling of some unsteady forms of filtration (in Russian), *Trudi In-ta Matem. i Mekh., Akad. Nauk UzSSR* no. 21, 75-78, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 633.

It is proposed to solve the linearized equation by Boussinesq (the equation of heat conductivity) on a thermal model, which took the shape of a metal (actually duralium was employed) bar with heating elements at each end, the temperature being regulated by a special relay. To measure the temperature along the length of the bar thermocouples were fitted. The bar has to be inserted into a balloon-shaped glass vessel in which a sufficient degree of rarefaction can be produced. The equation for the construction of the apparatus is given in a very general form. It is proposed to take into account the evaporation from the free surface by means of its analogy to the heat exchange from the bar's surface. Here, by virtue of several experiments, it is assumed that the magnitude of the evaporation is proportional to the depth of the underground level of the subsoil waters. This principle, apparently, can only be investigated as a special case [see: A. N. Kostyanov, N. N. Favorin, S. F. Averyanov, "Influence of irrigation systems on the character of sub-soil waters," Izd-vo Akad. Nauk SSSR, 1956]. No information of any sort is given regarding the accuracy of the solution carried out by the proposed method.

V. M. Shestakov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2646. Ruban, G. F., Influence of filtration flow on the construction of pressure hydro installations (in Russian), *Trudi Kishinevsk. S-kh. In-ta* **15,** 165-180, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 646.

A method is proposed for the calculation of the filtration below hydrotechnical pressure installations situated on non-rocky foundations. The method enables consideration to be given to the appearance of the horizontal anisotropy of the foundation's soils and the decrease of the magnitude of the filtration coefficient as the distance from the surface downward increases, this being due to the increase of stresses in the soil with the increase of depth. It is shown that consideration of these two factors markedly raises the efficiency of the vertical filtration passages by comparison with the horizontal. Consequently, in order to effect more economy in the working of pressure hydro installations a scheme with channelways is recommended, these channels being located at the commencement of the apron part of the construction, and also at the drainage of the foundation.

L. N. Pavlovskaya

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2647. Albo, P., Some aspects of flow of fluids in porous media (in French), *Rev. Inst. Fr. Petrole et Ann. Comb. Liquid* **13,** 7/8, 1117-1156, July/Aug. 1958.

First and second parts of paper have the character of a review. The first part contains a brief discussion of Darcy's law in isotropic and anisotropic media for one- and two-phase flow. In the second part it is shown that Darcy's law follows from the Navier-Stokes equations when inertia terms are neglected. Kozeny's theory, drag theories and a statistical theory of saturated permeability are reviewed briefly. Apart from the work of Scheidegger [*J. Appl.*

Phys. **25**, p. 994, 1954; AMR **8**(1955), Rev. 2897] no mention is made of important contributions made by soil scientists, e.g. Childs [AMR **11**(1958), Rev. 156 and earlier papers], Philip [AMR **11**(1958), Rev. 1063 and earlier papers].

In the third and final part, analytical solutions are obtained for a single well in an incompressible, saturated reservoir of constant depth, assuming radial flow and cylindrical symmetry. The well is supposed to be surrounded by a cylindrical region with a permeability differing from that in the rest of the reservoir. The compressibility of the fluid is taken into account. Cases treated are: production at constant pressure, production at constant output, and recovery after closure of the well, for reservoirs of finite and infinite horizontal extent, the former with and without intake.

D. A. De Vries, Holland

2648. Khein, A. L., Irregular flow of liquid and gas to a ring of batteries of incomplete wells distributed in an infinite stratum (in Russian), *Trudí Vses. Neftegaz. Nauk-i. In-ta* no. 10, 28–39, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12902.

The author, by using a method previously described by him, finds an approximate expression for the potential of mass-velocity on the face of a single incomplete well during unsteady filtration in an infinite stratum, the regime being elastic. An approximate solution of the problem is also given regarding the interaction of incomplete wells disposed symmetrically in a ring of batteries.

V. P. Pilatovskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2649. Pudovkin, M. A., The simplest example of the problem of the moving forward of the contour of a petroleum-bearing stratum (in Russian), *Uch. Zap. Kazansk. In-ta* **117**, 2, 86–90, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12903.

The problem is examined in G. S. Salekhov's setting [*Izv. Akad-Nauk Kazanak. Fil. SSSR. Ser. Fiz.-Mat. Tekhn. Nauk.* no. 6, 3–38, 1955] of the control of the contour of the petroleum-bearing stratum when the liquid is moving in a single-direction semi-infinite elastic layer, where the petroleum is found at the finite portion of the stratum, while the semi-infinite end contains the water. The motion conforms to the linear principle of filtration. The problem consists in finding a solution for the system

$$a_i^2 \frac{\partial^2 p_i(x,t)}{\partial x^2} = \frac{\partial p_i(x,t)}{\partial t} \quad \begin{pmatrix} i=1 \text{ with } 0 \leqslant x \leqslant x_0 \\ i=2 \text{ with } x \geqslant x_0 \end{pmatrix}, \quad t>0$$

with the following conditions

$$p_1(x,0) = p_2(x,0) = p_2(\infty,t) = 0$$

$$p_1(x,t) = p_2(x,t) \text{ with } x = x_0(t)$$

$$C_1 \frac{\partial p_1(x,t)}{\partial x} = C_2 \frac{\partial p_2(x,t)}{\partial x} \text{ with } x = x_0(t)$$

Here $x = x_0(t)$ is the flowing margin of the contour of the petroleum-bearing stratum, $p_1(x,t)$, $p_2(x,t)$ are the pressures in the zones of the petroleum and of the water, a_1^2, a_2^2 are the coefficients of flow. By using the method of the theory of generalized thermal potentials, author merges the solution of the given problem with Volterra's integral equation of the first order. As an example the case is examined where $x = x_0(t) = A\sqrt{t}$, where A is some constant.

V. A. Karpyichev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2650. Shchelkachev, V. N., Special features of the progressive flooding of wells in uniform- and non-uniform-layered sloping strata (in Russian), *Trudí Mosk. Neft. In-ta* no. 20, 13–22, 1957; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12904.

An investigation is made of the layered sloping stratum of constant power in a hydrodynamically complete well. It is assumed that the liquid only moves toward the well along the surfaces of the stratum's layers, that the motion conforms to the linear principle of filtration, while the differences in viscosity and the specific gravities of the petroleum and water are disregarded. With these assumptions operating, the process is investigated of the flooding of the well in a uniformly layered stratum, and then in a nonuniformly layered stratum. Formulas and graphs are obtained which characterize the flooding process in both these cases. Numerical examples are given.

V. A. Karpyichev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2651. Usenko, V. S., Approximate analysis of vertical systematic drainage (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 7, 119–122, July 1958.

Uniform vertical drainage into a well is discussed, in presence of an infiltration from the soil surface. Boussinesq equation is simplified and approximate formulas are derived for the variation of water table at the outer limit and for a total inflow into well. Complex problem leads to a logarithmic form of the depletion surface.

S. Kolupaila, USA

Geophysics, Hydrology, Oceanography, Meteorology

(See also Revs. 2331, 2423, 2450, 2518, 2597)

Book—2652. Slotnick, M. M., (edited by Geyer, R. A.), Lessons in seismic computing, Tulsa, Okla., The Society of Exploration Geophysicists, 1959, x + 268 pp. $5.50.

Subject-matter is elementary ray-theory in seismic prospecting. Book develops subject *ab initio*, and is designed for readers of limited mathematical attainment; only elementary calculus is used, and steps are explained in great detail. First section has 24 "lessons" covering reflection and refraction problems with single homogeneous layer separated from homogeneous medium below by plane interface, horizontal or dipping. Second section has six lessons in which reflection problem with dipping interface is considered three-dimensionally. Third section has five lessons on case of n horizontal homogeneous layers. Fourth (last) section has nine lessons on case of linear variation of velocity with depth.

K. E. Bullen, Australia

2653. Rykunov, L. N., Study of the character of the diminution of the amplitude of waves in the umbra zone on a model of the earth (in Russian), *Izv. Akad. Nauk SSSR, Ser. Geofiz.* no. 10, 1262–1265, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 356.

An investigation is made of the diffraction of seismic waves on the Earth's core by using the method of ultrasonic modelling. By use of an ultrasonic seismoscope on a model of the Earth a study was made of the influence of different mechanical properties of the core on the nature of the reduction of pressure of the waves in the umbra zone. The model of the Earth with a diameter of 38 cm was made from a melt of paraffin wax and polyethylene and presented in itself a sphere with a cavity filled with substances with different mechanical properties. The author made every possible attempt to satisfy approximately the basic criteria of similarity. The investigations showed the existence of a dependence of the wave condition in the umbra zone on the modulus of shear of the core.

S. S. Voit

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2654. Allais, M. F. C., Should the laws of gravitation be reconsidered? Part I, Abnormalities in the motion of a paraconical pendulum on an anisotropic support; Part II, Experiments in connection with the abnormalities noted in the motion of the paraconical pendulum with an anisotropic support; Part III, Complementary note, *Aero/Space Engng.* **18,** 9, 46–52, Sept. 1959; **18,** 10, 51–55, Oct. 1959; **18,** 11, p. 55, Nov. 1959.

The motions of a pendulum, suspended on a ball and resting on an anisotropic support, have statistically significant amplitude and periodic components of periods approaching 24 and 25 hours. The installation and the instrumental technique are briefly described. The observed motions result from four conjugate effects: the Foucault effect, an effect of the suspension release, the aleatory influence of the balls, and, finally, a periodic influence. The observed periodic structure cannot be considered as due to the disturbances of an aleatory order. Neither can it be considered as produced by an indirect influence of known factors (temperature, pressure, magnetism, etc.). Finally, it cannot be identified with periodic lunisolar effects resulting from the actual theory of gravitation. The irregularities ..., whose order of magnitude is of approximately a few millionths of gravity, do not in fact disagree with any of the experimental results arrived at either in the astronomical domains or on the earth's surface. At this stage of the discussion the observed effects must be considered as produced by the direct action of a new field.

From author's summary by K. Magnus, Germany

Book—2655. Stommel, H., The Gulf Stream—a physical and dynamical description, Berkeley, Calif., University of California Press, 1958, xiii + 202 pp. $6.

Phenomenon of the Gulf Stream, and also other ocean currents, presents many interesting problems, not only for oceanographers. Author of this new and interesting monograph rejects a usual opinion on the Stream as a "warm river in a cold ocean". He introduces two modern theories: of viscous boundary layer and of inertial boundary layer. Particularly mysterious is the meandering of the Stream in the ocean and fluctuations in the currents.

Although the modern theories are not yet proved definitely, this publication is an important step forward in the investigation of that important phenomenon. Methods of observation are mentioned in a few pages only. Bibliography is very extensive. Engineers and geographers will enjoy reading this nicely edited book.

S. Kolupaila, USA

2656. Zinkovich, V. P., New works connected with studies of the hydrodynamics of seashores (in Russian), *Meteorol. i Gidrologiya* no. 10, 43–47, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 355.

Descriptions are given of some of the results of the investigations on wave action and the motion of silt on the coastal strips of the Black sea, carried out by the laboratory of sea coasts of the Oceanological Institute of the Academy of Science, SSSR. In particular, details are given of the determination of the asymmetry of the duration of action of direct and return flows of water at the bottom (2.0); the asymmetry of mean and maximum pressures (up to 2.8), and others. The methods of investigating the migration of silt along the shore are described. Evidence is furnished of the turbidity of the water in the coastal area attaining $30g/l$; of the velocity of migration of the suspended silt up to 3 km/hr with a rate of flow along the shore of 4 km/hr; of the velocity of motion of bottom silt in the troughs between the waves of up to 0.5 m/hr. It is noted that with wave heights $h = 1$m the suspended silt can travel 20 km in 24 hours. In this process the bulk of the silt may amount to tens of thousands of m^3 in the same period. A vibration tube is described for taking samples of bottom silt from thicknesses of up to 3–5 m.

A. S. Ofitserov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2657. Soskin, I. M., and Denisov, V. V., Calculation for the stationary horizontal circulation of the waters of the Baltic Sea for two types of wind fields (in Russian), *Trudi Gos. Okeanogr. In-ta* no. 41, 31–45, 1957; *Ref. Zh. Mekh.* no. 1, 1959, Rev. 360.

Paper gives the results of calculations for full flows of the Baltic sea. Authors draw on the theory of full flows by V. B. Stokman. In order to obtain a qualitative picture of the field of full flows ψ, rot T was calculated for two characteristic types of the wind field. (Rot T is the vertical component of a vortex due to the tangential pressure of a wind T). The authors computed the field of T by the field of the wind, making use of the known quadratic relation. Field ψ obtained in this way was accepted as the initial distribution of full flows when solving the problem by the iteration method. Here the authors utilized the results obtained by A. I. Felzenbaum [*Meteorol. i Gidrologiya* no. 3, 16–22, 1955; *Tr. Gos. Okeanogr. In-ta* no. 29, 65–91, 1955], in conformity with whose views function ψ is determined by the solution of Poisson's equation

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} = \frac{1}{k}\,\mathrm{rot}\ T \qquad [1]$$

where k is the proportionality coefficient. Results are given for the numerical solution of Eq. [1] for each of the two methods of assigning the boundary conditions: the adhesion condition on the shore contour of the Baltic Sea and the slip condition on the assigned boundary, placed sufficiently closely to the shore. It is noted that the picture of the circulation calculated by means of the boundary conditions of slip appears to be the clearer and the more probable of the two. Assuming that the field of the function of full flow only determines the direction of the flow the authors computed the velocity of the current and the slopes of the sea bed level by rough approximations of Ekman's formulas. The calculations showed that the velocities of the gradient currents are not large (1 – 5 cm/sec) and only attain 8 – 10 cm/sec in shoal water regions. The materials obtained in single observations during expeditions on flows and the mean-value data gathered from floating buoy observations showed that the divergence in direction of calculated and actual flows was of the order of ± 40. Some figures are also given as the result of observations on the distribution of temperature, density and salinity by depth in the Baltic Sea. The layer showing a "jump" in temperature is found at a depth of 20–30 m and increases from north to south. Even violent and continuous winds do not destroy this layer but only slightly alter its position in depth.

A. S. Sarkisyan

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2658. Durst, C. S., Crossley, A. F., and Davis, N. E., Horizontal diffusion in the atmosphere as determined by geostrophic trajectories, *J. Fluid Mech.* **6,** 3, 401–422, Oct. 1959.

A theory is presented for predicting the horizontal diffusion in the atmosphere. Theory is compared with timed trajectories initiated twice a day into the geostropic wind. A standard deviation is suggested.

A. S. Andes, USA

2659. Faller, A. J., and von Arx, W. S., The modeling of fluid flow on a planetary scale, Proceedings, Seventh Hydraulics Conference, Iowa Institute of Hydraulic Research, June 16–18, 1958; Iowa City, Iowa, State Univ. of Iowa, 1959, 53–72.

Laboratory models of ocean circulation patterns have been developed having the same Rossby number, large Reynolds numbers, and means of introducing energy sources, and boundary conditions.

These models, initially undertaken on rudimentary physical bases, have contributed to the development of sound physical concepts. Atmospheric models with free surfaces have similarly demonstrated fronts and wave cyclones.

A. S. Andes, USA

2660. Bazilevich, V. V., Influence of atmospheric turbulence on the audibility of sounds in the atmosphere (in Russian), *Trudi Gl. Geofiz. Observ.* no. 73, 50–53, 1958; *Ref. Zh. Mekh.* no. 11, 1958, Rev. 12213.

The weakening of the intensivity of sound I with increase of distance x in a turbulent atmosphere is described by the principle $I = I_0 X e^{-(\alpha_T + \alpha_d)x}$, where α_T, α_d are coefficients resulting from the weakening of the thermal and dynamic turbulence. For α_T, Ertel obtained the formula

$$\alpha_T = 4\pi\eta\sigma(T)/\lambda_0 T_{mean}$$

where $\sigma(T)$ is the mean quadratic value of the pulsations of the temperature, T_{mean} is the mean temperature, λ_0 is the length of the sound wave, η is a numerical coefficient. A simplified investigation results in obtaining the following formula for α_d

$$\alpha_d = 4\pi\theta\sigma(u)/\lambda_0 c_0$$

where $\sigma(u)$ is the mean quadratic value of the pulsations of velocity, c_0 is the mean velocity of sound, $\theta = \sqrt{3n_0}$ is a numerical coefficient (n_0 being the mean value for the coefficient of refraction). This formula is analogous to the formula obtained earlier by D. I. Blokhintsev ["The acoustics of a heterogeneous moving medium," OGIZ, 1946].

A. S. Monin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2661. Mashkovich, S. A., Consideration for the effect of the nonlinear terms of the equations when solving the problem on the short-period prognosis of pressure and temperature (in Russian), *Trudi Tsentr. In-ta Prognozov* no. 60, 22–31, 1957; *Ref. Zh. Mech.* no. 11, 1958, Rev. 12786.

Several methods are proposed for the approximate solution of nonlinear equations for the prognosis of meteorological elements. In particular, the solution is investigated of the problem of the pressure at a mean level of the atmosphere in the regions of the northern hemisphere. Here the author follows E. N. Blinov, by using for the solution of this problem the equation of the transmission of a vortex on a spherical Earth. The solution of the linearized (in relation to the zonal motion) equation for the vortex is worked out in the form of series of spherical functions with coefficients determined by the original value of the function for the current ψ

$$\psi_1 = \sum_{n,m} C_n^m \sin(\sigma_n^m t + m\lambda + \varphi_n^m) P_n(\cos\theta) \qquad [1]$$

where

$$\sigma_n^m = \frac{2(\alpha+\omega)}{n(n+1)} m - \alpha m$$

The proposal is put forward to improve this solution by means of corrections relating to the nonlinearity of the vortex equation. One of the proposed methods to find corrections for ψ_1 consists of the following procedure: the nonlinear terms in the vortex equation (not taken into account in the linear approximation) are transferred to the right-hand side of the equation. In these items the sought function ψ is replaced by the solution of the linearized equation, represented by the series [1]. The products obtained from the series are converted into a series with spherical functions. Finally, the problem merges with the solution of a linear heterogeneous equation with a known right-hand side. The right-hand side is found in the form of the sum-total of paired products from the coefficients of the original field for ψ. Another method is also proposed for the solution of the equation for nonlinear corrections. Namely, the nonlinear combination of the derivatives of ψ by the coordinates transposed to the right-hand side of the equation does not expand again in a series with spherical functions, but is examined as some known quantity obtained as the results of the linear solution of the function of time Φ. The value of this function in various points of the chart can be determined by the field of the current's function, calculated in a linear approximation, for instance, by using numerical differentiation. Furthermore, function Φ can be represented in the form of a series with spherical functions, with coefficients depending on time t. A heterogeneous equation is obtained when determining the nonlinear correction ψ_2. Its solution can be expressed, in particular, with the help of an integral containing the function of influence

$$\psi_2 = -\int_0^t \int_0^{2\pi} \int_0^{\pi} G(\theta', \lambda-\lambda', t-\tau)\Phi(\theta', \lambda', \tau)\,d\theta\,d\lambda'\,d\tau' \qquad [2]$$

where

$$G = \sum_n \frac{2n+1}{4\pi n(n+1)} \sin\theta' P_n(\cos\gamma_n)$$

$$\cos\gamma_n = \sin\theta\sin\theta'\cos[\sigma_n(t-\tau) + (\lambda-\lambda')] + \cos\theta\cos\theta'$$

$$\sigma_n = \frac{2(\alpha+\omega)}{n(n+1)} - \alpha$$

(The method of solution for the vortex equation with the aid of the function of influence was proposed by E. N. Blinov. By its means, actually, solution [1] of the linearized equation for the vortex was brought to such a form.) The calculation of the derivatives of the high (third) order of ψ for the determination of Φ can be replaced by the calculations based on the first derivatives. For this purpose solution [2] is converted to the corresponding form with the aid of a double-stage piecewise integration. In the process new functions of influence are obtained, which contain the second derivatives from G. Graphs are furnished for these functions and for function G for different values of the arguments. The application of the given method permitted the evolution of more precise prognoses, constructed within the framework of the linear theory.

In the concluding part of the paper an investigation is carried out of the numerical solution of the nonlinear equations of the atmosphere's dynamics (short-term prognosis) without preliminary linearization. Here the problem is solved of the prognosis in a quasi-geostrophic approximation on a "flat" Earth. The atmosphere is considered to be polytropic. The solution of the corresponding system of equations relative to the first approximation of the geopotential by time $\partial H/\partial t$ is taken in the form proposed by N. I. Buleev and G. I. Marchuk—in the form of spatial integrals containing the advection of temperature and the advection of vortex formation multiplied by the corresponding Green's functions. The use of the polytropy hypothesis permits the expression, here, of the pressure and temperature in the whole region through the pressure on two fixed levels. As the result, the expression for $\partial H/\partial t$ is brought to the surface integrals, distributed over the two fixed levels. To serve as examples of these equations isobaric surfaces of 500 and 1000 mb are selected. For these levels the initial data are taken and for the same levels prognosis H is obtained. The integration interval by time is divided up into a number of steps δt. The geopotential H as a function of time is formed by Euler's method (the tangential method), as soon as the values $\partial H/\partial t$ for an arbitrary moment can be calculated. When calculating the derivatives and integrals by the horizontal coordinates x, y, the corresponding differences approximations are introduced. For the solution of the problem a scheme is devised for the electronic calculator BESM. On this machine the prognosis for a 24-hour forecast covering the European and West Siberian areas is made in approximately 40 minutes.

S. L. Belousov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Naval Architecture and Marine Engineering

(See Revs. 2313, 2435, 2588, 2590)

Friction, Lubrication and Wear

(See also Revs. 2258, 2609)

2662. Taylor, C. F., The effects of unit size on friction and wear, Proceedings of Engine Wear Symposium, 6–7 May 1958, Southwest Research Inst., San Antonio, Texas, vi + 266 pp.

By means of dimensional analysis it is shown that mechanically similar machines are limited basically to the same maximum linear velocity (such as tip speed in rotating machines, or mean piston speed in reciprocating machines) by stress considerations. Hence the maximum rotational speed of such machines tends to vary inversely as the characteristic length. For similar machines operating at same linear velocity, the friction force per unit area at corresponding points tends to be the same, and all bearings tend to operate with equal degree of safety, if the lubricant viscosity is made to vary in direct proportion to characteristic length. Under these conditions, the "wear damage," or the ratio of wear depth to characteristic length, obtained in a given time is shown to decrease with increasing characteristic length. This is given as the basic explanation for the tendency toward increasing life with increasing unit size for similar machines. The paper is well supported by internal-combustion engine data.

P. M. Ku, USA

2663. Ito, S., Honda, K., and Ishiyama, K., Wear of carbon steel weld metal, Parts I, II, and III, Microscopical observations of the changed layers of the worn surface; The effect of previous heat treatment of the specimen upon the wear and the structural changed layers of the worn surface; The effect of the rubbing conditions upon the wear and the structural changed layers of the worn surface, *J. Mech. Lab., Tokyo,* **4,** 2, 49–56, 1958; **5,** 1, 24–29; **5,** 1, 30–34, 1959.

2664. Niebylski, L. M., Antler, M., and Brockway, L. O., Investigation of wear by electron diffraction, *ASLE Trans.* **1,** 2, 304–311, Oct. 1958.

2665. Bearings, lubricants and lubrication—A digest of 1958 literature, *Mech. Engng.* **81,** 10, 56–69, Oct. 1959.

2666. Polnitskii, K. A., Measurement of friction force in piston engines, *Measurement Techniques* no. 1, 31–34, Aug. 1959. (Translation of *Izmeritel'naia Tekhnika,* no. 1, 27–30, Jan./Feb. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2667. Mow, C. C., and Saibel, E., The gas lubricated finite slider bearing, Proc. 6th Midwest. Conf. Fluid Mech., Austin, Texas, Sept. 1959; Austin, Texas, Univ. Press, 383–405.

Since for the calculation of the lubricating flow in a bearing the inertia terms of the Navier-Stokes' equations may be neglected, the same expressions for the velocities result in a compressible and in an incompressible lubricant. Differences only originate from using the continuity equation which in the case of compressible fluids contains the density of the lubricant. By inserting the velocities into this equation a Reynolds equation is attained with the product $\rho\,\partial p/\partial x$ instead of $\partial p/\partial x$ and $\rho\,\partial p/\partial y$ instead of $\partial p/\partial y$. Authors assume the flow to be isothermal and eliminate ρ by means of the state equation for ideal gases. So they obtain the nonlinear partial differential equation $\partial/\partial x\,[b^3 p\,\partial p/\partial x + 6\,\mu U b p] + \partial/\partial y\,[b^3 p\,\partial p/\partial y] = 0$ (b = film thickness; μ viscosity of the lubricant; p pressure; U velocity of the slider).

As the slope of the inclination of a slider bearing ε is very small authors use a perturbation method and insert the power series $p(x,y) = p_0(x,y) + \varepsilon p_1(x,y) + \varepsilon^2 p_2(x,y) + \ldots$ for p into the above equation. Then the equation is satisfied if the sum of the terms of equal ε-powers vanish. This condition yields partial differential equations which may successively be used for determining $p_0, p_1, \ldots$. The equation for p_0 is of elliptical form. Therefore p_0 may have a maximum or a minimum at most on the boundary of the slider. Yet because there p_0 equals the ambient pressure p_a it does not possess a maximum or a minimum anywhere and equals p_a everywhere. By introducing the nondimensional quantities $\bar{x} = x/a$ (a = length of the bearing), $\bar{y} = y/b$ (b = width of the bearing) and $\bar{p}_n = p_n/p_a$ into the equations originating from the terms with ε^1 and ε^2 authors obtain equations for $\bar{p}_1$ and $\bar{p}_2$ which contain the dimensionless parameter $\beta = 6\mu U a/p_a b_0^2$ besides $\alpha = b/a$ and a/b_0 (b_0 = outlet film thickness). At first they dealt with the case of an infinite width slider. For the finite width slider they put $\bar{p}_n(x,y) = \Phi_n(x) + \psi_n(x,y)$ where $\Phi_n(x)$ is the pressure for the infinite width slider and determined $\psi_n(x,y)$ by the method of separation of variables.

The pressure distributions so calculated are lower and have their maximum nearer to the outlet of the slider than in the case of the lubrication with an incompressible fluid. Further, with increasing U the load capacity for a given geometrical configuration of the bearing seems to approach an upper limit whereas it is proportional to U in the incompressible case.

U. Rost, Germany

2668. Simkin, G. S., and Fomina, O. P., Measurement of the waviness of bearing rings, *Measurement Techniques* no. 2, 131–134, Aug. 1959. (Translation of *Izmeritel'naia Tekhnika,* no. 2, 11–13, Mar./Apr. 1958 by Instrument Society of America, Pittsburgh, Pa.)

2669. Hays, D. F., Plane sliders of finite width, *ASLE Trans.* **1,** 2, 233–240, Oct. 1958.

This paper presents an analytical solution, in convergent series form, of the Reynolds equation pertaining to the hydrodynamics of fluid films found in thrust block bearings. It gives curves for the load capacity, frictional resistance, center of pressure, coefficient of friction, and rates of flow, each of which is extremely well prepared.

The results will be most helpful to designers.

E. K. Gatcombe, USA

Books Received for Review

BATCHELOR, G. K., The theory of homogeneous turbulence, Students' edition, New York, Cambridge University Press, 1959, xi + 197 pp. $3.75. (Paperbound)

CALLEN, H. B., Thermodynamics, New York, John Wiley & Sons, Inc., 1960, xv + 376 pp. $8.75.

CARROLL, R. L., The aerodynamics of powered flight, New York, John Wiley & Sons, Inc., 1960, ix + 275 pp. $8.50.

CRANDALL, S. H., and DAHL, N. C., edited by, An introduction to the mechanics of solids, New York, McGraw-Hill Book Co., Inc., 1959, ix + 444 pp. $8.50.

EIRICH, F. R., Rheology, theory and application, Vol. III, New York, Academic Press, 1960, xvi + 680 pp. $21.

GILMONT, R., Thermodynamic principles for chemical engineers, Englewood Cliffs, N. J., Prentice-Hall, Inc., 1959, xxv + 339 pp. $11.

HAWTHORNE, W. R., and OLSON, W. T., editors, Design and performance of gas turbine power plants (High speed aerodynamics and jet propulsion, Vol. XI), Princeton, N. J., Princeton University Press, 1960, xiii + 563 pp. $15.

LOITSIANSKII, L. G., Mechanics of liquids and gases (in Russian), Moskva, Gosudarstvennoe Izdatel'stvo Fiziko-Matematicheskoi Literaturv, 1959, 784 pp.

Netherlands Engineering Consultants, River studies and recommendations on improvement of Niger and Benue, Amsterdam, North-Holland Publishing Co., 1959, ix + 1000 pp. + 2 maps.

OPPELT, W., Kleines Handbuch technischer Regelvorgange, 3rd ed., Weinheim, Verlag Chemie, Gmbh., 1960, 632 pp. DM 39.60.

PRESS, H., Stauanlagen und Wasserkraftwerke, Part II: Wehre, 2nd ed., Berlin, Wilhelm Ernst & Sohn, 1959, xi + 395 pp. DM 56.

SAUNDERS, H. E., Hydrodynamics in ship design, Vols. I and II, New York, Society of Naval Architects and Marine Engineers, 1957, xxxv + 648 pp.; xxiii + 980 pp. $30. the set.

SWAINGER, K., Analysis of deformation, Vol. 4: Waves and vibrations, New York, The Macmillan Co., 1959, xxvii + 370 pp. $15.

TONG, K. N., The theory of mechanical vibration, New York, John Wiley & Sons, Inc., 1960, xii + 348 pp. $9.75.

UMANSKOGO, A. A., Raschet prostranstvennykh konstruktsii, Moskva, Gosudarstvennoe Izdatel'stvo Literatury po Stroitel'stvu Arkhitekture i Stroitel'nym Materialam, Vol. I, 1950, 342 pp. 20r; Vol. II, 1951, 479 pp. 26r; Vol. III, 1955, 559 pp. 21r 10k; Vol. IV, 1958, 554 pp. 26r; Vol. V, 1959, 555 pp. 29r 35k.

How to Obtain Copies of Articles Indexed

Photocopy or microfilm copies of articles reviewed in this issue will be provided whenever possible. Orders should specify the APPLIED MECHANICS REVIEWS volume and review number.

Except as indicated below, address orders to LINDA HALL LIBRARY, 5109 Cherry Street, Kansas City 10, Mo., and include remittance to cover costs. Orders to Linda Hall Library may also be placed by teletype, using the number KC334. Complete copies of the articles reviewed in Referativnyi Zhurnal and reprinted in AMR are received by the editors of AMR or by Linda Hall Library a considerable length of time after publication of the review, and therefore are not immediately available. Photocopy costs are 35¢ for each page of the article photocopied, minimum charge $1.25; microfilm costs include a service charge of 50¢ per article plus 3¢ per double page, minimum charge $1.25. *The applicant assumes responsibility for questions of copyright arising from copying and the use made of copies. Copyright material will not be reproduced beyond recognized "fair use" without consent of the copyright owner.*

To secure copies of reviewed papers from English-translated issues of Russian journals, apply to the English language publisher given in the review heading. Photocopying of such translations is often expressly forbidden. Costs will vary with the publisher.

"Proved" Technical Aids for Engineers

MECHANICAL IMPEDANCE METHODS FOR MECHANICAL VIBRATIONS

A reference for engineers specializing in vibration analysis and control

This book shows how impedance methods apply to lumped and continuous systems of simple and moderate complexity, reviews measurement techniques, demonstrates the power of digital computers by comparing the calculated and measured characteristics of a highly symmetrical system of moderate complexity, gives measured values of typical structures of large size and high complexity, discusses the importance of the impedance in influencing shock and vibration spectra measured in field service, indicates how to apply impedance methods to the calculation of vibration isolator effectiveness, treats impedance of some disordered systems, shows how impedance methods may be used to find the response to random excitation, and describes a dynamic stiffness method that has proved useful in predicting critical speeds of steam turbines.

Published 1958 **$5.50***

THERMODYNAMIC AND TRANSPORT PROPERTIES OF GASES, LIQUIDS, AND SOLIDS

A valuable and advanced survey of data and techniques on the thermal properties of important materials engineering

The methods and important experimental findings in this book are based on the work of the foremost authorities in the field. They include a survey of the present theoretical and experimental state of the science, a large amount of new data on current experimental and theoretical techniques, including thermodynamic and transport properties, PVT data and equation of state, some experimental transport properties, and high thermodynamic properties of gases. The forty-two papers in this book were originally presented at an ASME Symposium on Thermal Properties.

Published 1959 **$12.50***

SHOCK AND VIBRATION INSTRUMENTATION

Gives the principal results of research and development programs sponsored by various agencies.

Random vibration, effect of nonrigid structures on vibration isolation, hysteresis and slip damping, vibration and shock testing, design approaches, and analog methods are some of the subjects covered. Emphasis is placed throughout on applicable basic principles rather than on explicit problems of only passing interest.

Contents: The Evaluation of Mounts Isolating Nonrigid Machines from Nonrigid Foundations. Experimental Study of the Effects of Foundation Resilience on Vibration Isolation. Effect of Material and Slip Damping on Resonance Behavior. Shock and Vibration Environments. Mechanical Design for Random Vibration and Shock. Influence of Electrical and Motional Impedance on the Control and Performance of Some Vibration Machines. Shock Testing Machines and Procedures. Damaging Potential of Shock and Vibration. High Speed Computing Methods for Shock and Vibration Problems.

Published 1956 **$5.00***

STRUCTURAL DAMPING

Provides a wealth of information useful in engineering design

This book discusses such structural damping techniques as interfacial coulomb slip, viscoelastic laminate damping, and coulomb or viscoelastic junction damping. The information has been written by authorities in the field.

Contents: Energy Dissipation Mechanisms in Structures, with Particular Reference to Material Damping. A Review of Progress in Analysis of Interfacial Slip Damping. Damping of Plate Flexural Vibrations by Means of Viscoelastic Laminae. Vibrational Energy Dissipation at Structural Support Junctions. Measurement of Damping. Material Design for Resonant Members. Selected Bibliography on Structural Damping.

Published 1959 **$4.25***

DESIGN DATA AND METHODS

Replete with data, procedures and solutions—all in a form most useful to design engineers.

Here in forty-one contributions and 200 pages are data applying to the stresses and deflections of engineering structures, fluid mechanics problems, bearing design, vibration, and balancing.

Contents: Stresses and Deflections in Circular and Rectangular Plates. Circular Beams Loaded Normal to the Plane of Curvature. Rectangular Plate—Subjected to Hydrostatic Tension and to Uniformly Distributed Lateral Load. Design Data for Flat Circular Plates with Central Holes. Deflections and Moments for Rectangular Plates with Hydrostatic Loading. Critical Loads on Variable-Section Columns in the Elastic Range. Analysis of Elastic Two-and Three-Section Short Columns. Computation of Flexural-Torsional Buckling Loads. Data Sheets for Design of Piping. Expansion of Formulas for Calculating Loads, Rotation, and Deflections of Quarter Bends and Tangents of Pipes. Factors of Stress Concentration Photoelastically Determined. Factors of Stress Concentration for Slotted Bars in Tension and Bending. Torsional Stresses in Shafts Having Grooves or Fillets. Helical Compression and Tension Springs. Calculation of Rectangular Bar Helical Springs. Calculation of Stress in Crane Hooks. Thermal Stress. Stresses in Pressure Vessels. Design of Press- and Shrink-Fitted Assemblies. Working Stresses. Stress-Concentration Factors for Single Notch in Flat Bar in Pure and Central Bending. On the Maximum Numerical Value of the Tangential Stress in Thick-Walled Cylinders. Stresses in Curved Beams—A Tabular Method of Solution Based on Winkler's Theory. Method of Characteristics for Two-Dimensional Supersonic Flow—Graphical and Numerical Procedures. Tables for Numerical Solution of Problems in the Mechanics and Thermodynamics of Steady One-Dimensional Gas Flow Without Discontinuities. A Chart for Oblique Shock Waves in Water. Applying Bearing Theory to the Analysis and Design of Journal Bearings. Vibration Problems—Systems of One Degree of Freedom. Vibration Problems—Friction and Damping in Vibrations. Balancing of Rotating Apparatus. Harmonic Coefficients of Engine Torque Curves. Torsional Vibration Modes of Tapered Bars. Frequency of Vibration of Rectangular Isotropic Plates.

Published 1953 **$4.00***

Proceedings, 3rd U. S. NATIONAL CONGRESS OF APPLIED MECHANICS

Presents the findings of original researches and discusses the current approach to problems

Within this 904-page volume are reports of important studies in the fields of dynamics, vibration, elastic waves, elasticity, elastic structures, plasticity, viscoelastic flow, fracture, fluid flow, aerodynamics, and heat transfer. There are also discussions of new concepts and methods, and a large amount of new data which will aid in generating new ideas and new approaches toward solving other problems of the applied mechanics field.

Published 1958 $20.00 to members and nonmembers

***20% discount to ASME members.**

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
29 West 39th Street New York 18, N. Y.

Preview of Number 6,
Volume 23, 1959

PMM

Journal of

APPLIED MATHEMATICS AND MECHANICS

M. D. LADYZHENSKII: Hypersonic flow around bodies in magnetohydrodynamics

V. V. LUNEV: Hypersonic flow of a heat conducting gas past a cone

V. N. ZHIGULEV and Iu. I. ZHILIN: On bodies of minimum wave resistance

V. A. KOVALEVA: On non-steady motion of a wing of rectangular plan form

V. N. NIKOLAEVSKII: Convective diffusion in porous media

A. I. SAFRONCHIK: Rotation of a cylinder with variable angular velocity in a visco-plastic medium

V. V. RUMIANTSEV: On the stability of rotational motions of a rigid body with a liquid inclusion

L. M. MARKHASHOV: On characteristic indeces of the solutions of a linear differential equation of second order with periodic coefficients

G. N. PYKHTEEV: On the evaluation of certain singular integrals with a Cauchy-type kernel

S. A. TUMARKIN: Asymptotic solution of a linear non-homogeneous differential equation of second order with a transition point, and its application to the analysis of toroidal shells and blades

G. Ia. POPOV: Bending of an infinite plate on elastic half-space with the modulus of elasticity varying with depth

S. A. SHESTERIKOV: On the criterion of stability in creep

D. D. IVLEV: On the theory of ideal plastic anisotropy

L. Ia. KOSACHEVSKII: On the propagation of elastic waves in two-component media

N. I. KRISTESKU: On the propagation of elasto-plastic waves under combined loading

I. Sh. RABINOVICH: On a problem of equilibrium of the elastic half-space

A. I. KALANDIIA: On stresses in an elastic half-plane

V. M. DEEV: On the forms of the general solution of the three-dimensional problem of the theory of elasticity, expressed with the aid of harmonic functions

I. Z. PIROGOV: On the stability of a gyroscopic system

L. S. GNOENSKII: On the accumulation of disturbances in non-stationary linear impulsive systems

I. M. ASTRAKHAN and S. S. GRIGORIAN: On the complete system of equations of a compressible visco-plastic fluid

G. L. GRODZOVSKII: Self-similar motions with hydraulic waves in the case of "shallow water"

A. G. KULIKOVSKII and G. A. LIUBIMOV: Remarks regarding the structure of the perpendicular magnetohydrodynamic shock wave

PMM, JOURNAL OF APPLIED MATHEMATICS AND MECHANICS is an English translation of the Soviet journal, "Prikladnaia Matematika I Mekhanika". It is published bimonthly under the sponsorship of The American Society of Mechanical Engineers. Annual subscription rate: $35.00 ($28.00 to ASME members).

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Abramson, H. N. 2590
Adams, M. C. 2511
Ades, C. S. 2270
Akhachinskii, V. V. 2151
Aksel'rad, E. L. 2219
Alba, P. 2647
Alef, W. 2435
Allais, M. F. C. 2654
Amsler, R. 2440
Ando, T. 2447
Andrews, D. H. 2487
Annaratone, D. 2274
Anthony, F. M. 2297
Antler, M. 2664
Antsiferov, V. S. 2618
Armenakas, A. 2236
Asaturin, A. Sh. 2337
Ashley, H. 2588
Au, T. 2213, 2307, 2313
Augenstein, B. W. 2605
Ayers, E. F. 2596
Bachmann, R. W. 2449
Ball, J. W. 2328, 2342
Balmer, H. A. 2164
Baltrukonis, J. H. 2225
Bamford, H. E., Jr. 2598
Baron, J. R. 2517
Barraclough, T. W. 2453
Barre, H. J. 2636
Barta, J. 2304
Bartenev, G. M. 2261
Bartenev, V. S. 2216
Bartkowiak, A. 2536
Batkov, A. M. 2141
Baumgartner, F. 2440
Bazilevich, V. V. 2660
Beane, B. J. 2419
Beckwith, D. A. 2352
Belles, F. E. 2542
Bendat, J. S. 2117
Benetin, J. 2644
Benjamin, T. B. 2432
Benson, R. S. 2472
Beresnev, B. I. 2256
Bergh, S. 2283
Berlot, R. R. 2425
Berry, P. E. 2323
Bertodo, R. 2271
Bigelow, S. C. 2148
Biot, M. A. 2170
Black, C. 2481
Blankfield, Judith 2577
Bleich, H. H. 2211, 2250
Bobylev, A. V. 2292
Bock, A. 2315
Boggess, R. L. 2450
Bogusz, W. 2139, 2232
Boiarinov, V. S. 2144
Bolotin, V. V. 2220
Bolshakova, V. V. 2331
Bol'shanina, M. A. 2191
Borbely, S. 2501
Boyars, C. 2613
Bragg, S. L. 2552
Brandt, A. A. 2581
Braslow, A. L. 2401
Brewer, D. F. 2502
Brewster, D. B. 2348
Briggs, B. R. 2368
Brockway, L. O. 2664
Broglio, L. 2207
Brown, G. A. 2410
Buchman, A. S. 2628
Buchmann, E. 2620
Buckens, F. 2125
Bulakh, B. M. 2358
Bulygina, E. B. 2418
Burago, A. N. 2280
Burns, J. G. 2407
Bussard, R. W. 2563
Caglioti, V. 2357
Cahn, J. H. 2504
Cairnie, A. B. 2152
Camac, M. 2565
Campbell, F. B. 2332
Cappellari, J. O., Jr. 2606
Caracristi, V. Z. 2545
Carafoli, E. 2371
Caricato, G. 2160
Carlson, H. W. 2469
Cash, R. F. 2465
Chaiken, R. F. 2555
Chao, H.-Y. 2172
Chattarji, P. P. 2166, 2185
Cheaney, E. S. 2316
Chekmarev, A. P. 2255
Chen, L. H. 2309
Chernikin, V. L. 2337
Childs, W. H. J. 2407
Chipizhenko, A. I. 2292
Chu, S. T. 2370
Chu, W.-H. 2590
Clark, C. B. 2426
Clark, M. E. 2305
Clotfelter, B. E. 2576
Cohen, C. B. 2415
Connolly, T. J. 2490
Collier, R. D. 2453
Coolidge, J. L. 2130
Copp, M. R. 2423
Corcos, G. M. 2623
Corey, A. T. 2524
Cornog, R. 2376
Covert, E. E. 2574, 2575
Cox, R. A. 2488
Cresci, R. J. 2513
Crossley, A. F. 2658
Cutting, J. C. 2534
Dahler, J. S. 2486
Danilovskaya, V. I. 2503
D'Arga e Lima, J. 2231
Daum, C. R. 2640
Davis, N. E. 2658
Davletshin, Kh. G. 2324
Debler, W. R. 2353
Dem'ianov, Iu. A. 2208
Denisov, V. V. 2657
Dennis, F. L. 2146
Dennis, S. C. R. 2507
Derski, W. 2174
Devianin, E. A. 2120
Dianov, D. B. 2622
Dickinson, Nora B. 2276
DiMaggio, F. L. 2250
Dinnik, A. A. 2255
Donets, A. T. 2191
Doran, P. D. 2596
Douglas, D. A. 2290
Drake, D. G. 2420
Drell, I. L. 2542
Drozd, M. S. 2282
Drucker, D. C. 2215
Dugundji, J. 2588
Dunsmore, C. L. 2134
Durham, F. P. 2562
Durst, C. S. 2658
Dutt, S. B. 2166
Eagleson, P. S. 2454
Edigarov, S. G. 2337
Edwards, D. O. 2502
Edwards, W. B. 2576
Einbinder, H. 2381
Elder, R. A. 2518
Ellis, D. R. 2457
Erokhina, N. I. 2431
Ershov, L. V. 2157
Eskinazi, S. 2345
Evans, J. C. 2452
Evans, W. T. 2444
Fal'kevich, E. S. 2285
Faller, A. J. 2659
Farkas, G. 2523
Farrel, E. C. 2133
Fastov, N. S. 2264
Fatt, I. 2638
Fay, J. A. 2534
Feldman, S. 2403
Feodosiev, R.-E. V. 2204
Fine, B. 2548
Finkel'shtein, B. N. 2288
Finston, M. 2517
Fischer, J. 2635
Fleishman, B. A. 2149
Flitman, L. M. 2162
Flourney, J. M. 2571
Flowers, J. V. 2614
Flugge, S. 2479
Fok, T. D. Y. 2307
Fomina, O. P. 2668
Forrester, A. T. 2566
Fowler, R. G. 2576
Fraenkel, L. E. 2579
Frankland, J. M. 2262
Freeman, N. C. 2379, 2380, 2580
Frost, N. E. 2289
Fujii, Y. 2258
Fulton, F. M. 2568
Furlani, C. 2357
Galimov, K. Z. 2222
Galin, M. P. 2234
Galperin, A. I. 2195
Gaymann, T. 2269
Geiger, R. E. 2470
Geronimus, Ya. L. 2135
Gettings, H. 2494
Giatsintov, E. V. 2265
Gillespie, T. 2633
Ginevskii, A. S. 2406, 2437
Ginsburg, H. 2296
Gintsburg, Ya. S. 2189
Giulianetti, D. J. 2459
Glaser, H. 2522
Gleyzal, A. 2480
Glover, R. E. 2640
Gogsadze, R. Sh. 2210
Golecki, J. 2161
Goliamina, I. P. 2277
Golomb, M. 2124
Goloskokov, P. G. 2200
Golovanov, O. M. 2514
Goryunov, B. F. 2299
Goursat, E. 2126, 2127
Gouse, S. W., Jr. 2410
Grechko, V. P. 2255
Green, L., Jr. 2520
Greenspan, D. 2132
Greenwood, S. W. 2543
Greif, R. K. 2455
Grey, J. 2561
Gribben, R. J. 2404
Grosberg, P. 2348
Grumer, J. 2550
Guberman, I. O. 2206
Guerreiro, M. Q. 2311
Gundersen, R. 2383
Gunter, A. W. 2633
Gusak, I. V. 2341
Hall, W. J. 2259
Hamada, M. 2321
Hammack, J. B. 2448
Hammitt, A. G. 2369
Hammond, A. D. 2365
Hanel, R. A. 2153
Hangan, M. 2302
Hao, T.-C. 2224
Harman, T. C. 2504
Harper, Eleanor V. 2147
Harris, M. E. 2550
Hart, C. E. 2551
Hartwig, F. W. 2415
Hasegawa, Y. 2464
Hasimoto, H. 2583
Hays, D. F. 2669
Heidmann, M. F. 2554
Heins, A. E. 2626
Henderson, A., Jr. 2377
Henry, C. J. 2588
Herb, H. 2592
Herforth, L. 2621
Herrmann, G. 2171, 2236
Herzog, R. 2254
Heyson, H. H. 2446
Hickey, D. H. 2457
Hicks, R. 2201
Hirschfelder, J. O. 2505
Hoehne, V. O. 2460
Hogan, W. T. 2534
Holder, D. W. 2465
Holt, M. 2587, 2589, 2616
Honda, K. 2683
Hondros, G. 2275
Hord, R. A. 2484
Horowitz, R. 2450
Horton, E. A. 2401
Hoshizaki, H. 2380
Houpeurt, A. 2642
Hovanessian, S. A. 2136
Howell, R. R. 2474
Huang, Y.-S. 2306
Hudson, R. Y. 2333
Hunt, I. A., Jr. 2334

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Hwang, C. 2196
Iai, S. 2464
Ignat'ev, M. O. ...2158, 2183
Ingard, U. ..2584, 2624, 2625
Ioffe, I. A. 2498
Ionaitis, S. 2293
Ipatenko, A. Ya. 2519
Ishiyama, K. 2663
Ito, S. 2663
Ivanova-Chumakova, L. B. 2327
Ivlev, D. D. 2157, 2192
Jarre, G. 2390
Jain, P. C. 2411
Jenike, A. W. 2186
Jewel, J. W., Jr. 2446
Johnson, R. C. 2314
Johnson, R. H. 2373
Johnston, A. K. 2335
Johnston, P. J. 2377
Jones, J. J. 2471
Josefsson, A. 2283
Kalinina, R. V. 2246
Kaliski, S. 2239
Kalnins, A. 2198
Kaplunov, M. P. 2475
Kapur, J. N. 2572, 2615
Karashima, K. 2367
Kartashov, V. A. 2180
Katzen, E. D. 2608
Kawamura, R. 2367
Kaye, J. 2410
Keast, D. N. 2272
Keller, H. B. 2230
Kelly, M. W. 2455
Kerney, K. 2575
Kestin, J. 2351
Keulegan, G. H. 2427
Khein, A. L. 2648
Kholinyanskii, M. M. ...2301
Kilchevskii, M. O. 2184
Kilpi, J. 2273
Kim, C.-S. 2378
Kirkham, D. 2251
Kinnser, P. G. 2604
Kiselev, V. F. 2312
Kiseleva, I. V. 2235
Kiuchi, A. 2137
Klenov, V. B. 2645
Kluger, P. 2133
Knechtel, E. D. 2364
Knox, E. C. 2401
Kobayashi, A. S. 2229
Kobayashi, S. 2254
Koenig, D. G. 2455
Koga, T. 2482
Kogaev, V. P. 2265
Kolesnikov, A. L. 2194
Kol'ner, V. M. 2301
Korotaev, Yu. P. 2631
Kositskii, L. V. 2247
Kotlyar, I. V. 2553
Kotlyar, Ya. M. 2359
Kozlova, A. N. 2516
Krebs, R. P. 2551
Kreimerman, M. M. 2142
Kubanskii, P. N. 2510
Kudrin, O. I. 2473
Kudryashev, L. I. 2509, 2519
Kuhn, R. E. 2416
Kula, E. B. 2278
Kumar, S. 2197
Kurbjun, M. C. 2477
Kurtmulaev, R. Kh. 2581
Kuzovkov, N. T. 2140
Kvardakov, A. F. 2329
Kyner, W. T. 2529, 2530
Lagerberg, G. 2283
LaGow, H. E. 2450
Laitone, E. V. 2611
Lamb, C. A. 2326
Lambiris, S. 2536
Landis, F. 2531
Lang, R. 2441
Lapsley, J. T., Jr. 2254
Lapworth, K. C. 2382
Larisch, E. 2538
Larson, F. R. 2278
Lee, J. D. 2370
Lee, L. H. N. 2227
Lees, L. 2415
LeFur, B. 2512
Lehnigk, S. 2145
Lennov, V. G. 2295
Lenzi, E. 2600
Leonov, N. N. 2144
Levens, A. S. 2156
Levy, L. L., Jr. 2356
Libby, P. A. 2399, 2513
Liberatore, E. K. 2593
Liboff, R. L. 2578
Linden, D. A. 2146
Lidin, L. G. 2318
Limantov, G. 2639
Lindgren, E. R. 2338, 2339, 2340
Logan, M. J. 2504
Long, R. S. 2601
Lunchick, M. E. 2218
Ma, B. M. 2188
Maasland, M. 2251
MacCamy, R. C. 2626
McCloud, J. L., III 2445
McCullough, G. B. 2445
McCune, J. E. 2573
McGowan, G. E. 2546
McKay, J. M. 2595
MacKenzie, D. A. 2513
McKinney, L. W. 2365
McKinney, M. O., Jr. ...2456
McTigue, J. G. 2402
McVittie, G. C. 2577
Maezawa, T. 2321
Maizel', M. B. 2451
Maki, R. L. 2459
Makushkin, V. P. 2385
Maling, G. C., Jr. 2624
Malyuzhinets, G. D. 2627
Mandel, J. 2121
Mann, D. B. 2485
Manohar, M. 2336
Marciniak, Z. 2221, 2228
Markovets, M. P. .2176, 2281
Markstein, G. H. 2384
Marsden, D. J. 2461
Martellucci, A. 2372
Martin, J. A. 2409
Martinek, J. 2187
Mashirev, V. P. 2151
Mashkovich, S. A. 2661
Mednikov, I. A. 2203
Mercer, A. McD. 2507
Meyer, R. F. 2443
Michiyoshi, I. 2540
Miele, A. 2606
Miki, T. 2464
Mill, C. C. 2325
Mishuev, A. V. 2385
Miyao, K. 2165
Modrey, J. 2319
Moffatt, W. C. 2534
Moiseev, N. N. 2424
Molmud, P. 2609
Monakhov, N. M. 2417
Morland, L. W. 2249
Mort, K. W. 2444
Moskvitin, V. V. 2267
Mow, C. C. 2667
Muench, J. 2394
Mugler, J. P., Jr. 2366
Muki, R. 2163
Mukminova, A. G. 2637
Mumper, H. D. 2545
Munick, H. 2599
Murphy, C. H., Jr. 2422
Murray, W. D. 2531
Murthy, K. R. A. 2369
Nagamatsu, H. T. 2470
Nall, K. L. 2520
Nandeeswaraiya, N. S. ..2241
Natapov, B. S. 2285
Newcomb, T. P. 2506
Newell, G. F. 2351, 2352
Newman, B. G. 2346
Newmark, N. M. 2259
Newsom, W. A., Jr. 2468
Nicol, A. A. 2407
Niebylski, L. M. 2664
Nissan, A. H. 2348
Norbury, J. F. 2408
Nowinski, J. 2169
Obozov, I. P. 2287
O'Bryan, T. C. 2448
Ohji, M. 2413
Okushima, K. 2258
Onishchenko, V. I. 2476
Oravas, G.-A. 2214
Ordahl, D. D. 2570
Ostroumov, G. A. 2532
Ota, T. 2321
Overby, J. A. 2218
Overton, J. D. 2402
Oveyannikov, B. V. 2473
Paal, L. L. 2330
Padfield, Daphne G. 2276
Page, V. R. 2458
Palmer, H. B. 2544
Palmov, V. A. 2244
Pandalai, K. A. V. 2190
Panov, N. N. 2429
Parish, G. J. 2322
Parkus, H. 2168
Pasternak, R. N. 2629
Patel, S. A. 2190
Paullus, C. L. 2316
Pearce, D. C. 2527
Pearl, H. A. 2297
Pearson, A. O. 2462
Perkins, F. E. 2454
Petcu, V. 2303
Petrick, E. N. 2441
Petty, G., Jr. 2402
Pickett, E. B. 2332
Piechocki, W. 2173
Pierpont, J. 2128, 2129
Pinkney, H. F. L. 2245
Polik, B. M. 2261
Polikovskii, M. V. 2343
Polnitskii, K. A. 2666
Pond, H. L. 2350
Poocza, A. 2317
Poots, G. 2507
Powell, A. 2240
Proskuriakov, A. P. 2138
Pudovkin, M. A. 2649
Pullar, J. D. 2152
Rakhmatulin, Kh. A. ...2248
Raridan, W. C. 2316
Ratts, E. G. 2301
Razov, I. A. 2286
Rebinder, P. A. 2327
Reggini, H. C. 2226
Reiss, E. L. 2230
Riabinin, Iu. N. 2256
Riazanov, E. V. 2391
Rice, S. A. 2489
Richards, H. T. 2521
Richter, W. 2414
Riebe, J. M. 2594
Ringo, B. C. 2492
Robey, D. H. 2602
Rodden, W. P. 2123
Rogozhin, V. S. ..2421, 2430
Rolfe, S. T. 2259
Rom, F. E. 2560
Romanenko, E. V. 2277, 2617
Rosciszewski, J. 2386
Rose, H. E. 2634
Rosenblat, S. 2355
Rosenzweig, M. L. 2396
Ross, M. A. S. 2407
Rottner, J. 2630
Ruban, G. F. 2646
Rubin, S. 2557
Rusanova, E. I. 2242
Rusch, H. 2181
Rutkowski, E. V. 2569
Ryazanova, M. Ya. 2233
Rykunov, L. N. 2653
Sabersky, R. H. 2508
Sadowsky, M. A. 2167
Saibel, E. 2667
Sakuntala, M. 2576
Salvadori, M. G. 2211
Sandulescu, S. 2371
Sawada, T. 2436
Scala, S. M. 2533, 2607
Schaaf, S. A. 2393
Schaefer, J. W. 2345
Scheer, J. 2308
Scheidegger, A. E. 2643

(Continued on outside back cover)

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Schile, R. 2212
Schleusener, R. A. 2524
Schmidt, S. F. 2147
Schroder, J. 2131
Schuh, N. F. 2558
Schwanecke, H. 2438
Sears, W. R. 2573
Segalin, V. G. 2143
Sekoyan, S. S. 2641
Semerchan, A. A. 2641
Serensen, S. V. 2265
Shchelkachev, V. N. 2650
Sheer, R. E., Jr. 2470
Sheppard, H. R. 2296
Shevandin, E. M. 2286
Shevelev, V. V. 2287
Shield, R. T. 2186, 2215
Shifrin, A. S. 2483
Shindo, A. 2321
Shklovskaya-Kordi, V. V. 2354
Shulman, Y. 2586
Sidebottom, O. M. 2305
Sidorkina, S. I. 2389
Simeonov, S. V. 2209
Simkin, G. S. 2668
Simoyu, M. P. 2491
Singh, B. R. 2241
Sirazetdinov, T. K. 2591
Slotnick, M. M. 2652
Smith, C. T. 2541
Smith, D. E. 2118
Smith, H. J. 2360
Smith, N. D. 2488
Snodgrass, J. D. 2294
Sobolevskii, V. M. 2193
Sohn, R. L. 2612
Sokolov, F. A. 2238
Sokolova, I. N. 2428
Sokolowski, M. 2175
Solodkin, E. E. 2406
Soskin, I. M. 2657
Speiser, R. C. 2566
Spencer, N. W. 2450
Squire, W. 2412
Stark, V. J. E. 2361
Stavsky, Y. 2177
Stavtzeva, S. A. 2491
Steinman, D. B. 2243
Stepanov, P. M. 2434
Stepnov, M. N. 2265
Stern, H. 2150
Sternberg, E. 2163
Sterne, T. E. 2597
Stewart, R. B. 2485
Stivers, L. S., Jr. 2362
Stogryn, D. E. 2505
Stommel, H. 2655
Strscheletzky, M. 2347
Strack, S. L. 2587, 2616
Stratton, R. 2493
Stuhlinger, E. 2567
Sugawara, S. 2540
Summers, A. C. 2453
Summers, J. L. 2619
Suponitskii, A. M. 2349
Surikova, E. E. 2182
Surkov, V. 2639
Sutherland, G. S. 2559
Sutton, G. W. 2533
Swindeman, R. W. 2290
Szaniawski, A. 2387, 2388
Szechy, K. 2252
Takao, K. 2392
Takaoki, A. 2284
Tallent, R. J. 2558
Tamate, O. 2202
Tanaka, T. 2634
Tassi, G. 2300
Taylor, C. F. 2662
Taylor, E. S. 2405
Taylor, R. A. 2363
Thiel, R. 2320
Thomas, T. Y. 2263
Thomsen, E. G. 2254
Thunell, B. 2257
Thuring, B. 2603
Thurlow, G. G. 2496
Thurston, J. W. G. 2313
Tret'iakov, V. P. 2176, 2281
Troshin, Ya. K. 2539
Tsobkallo, S. O. 2279
Tsvylev, N. A. 2253
Tuck, J. L. 2582
Tulchii, V. I. 2205
Tyntekin, V. V. 2629
Uflyand, Ya. S. 2159
Urbanowski, W. 2179
Usenko, V. S. 2651
Usova, L. F. 2288
Vallander, S. V. 2439
Vandeghen, A. 2154, 2155
van der Bliek, J. A. 2400, 2463, 2467
Vandyshev, B. A. 2182
Varga, P. 2523
Varlet, H. 2310
Varvak, P. M. 2206
Vashchenko, Z. A. 2279
Venkatraman, B. 2190
Vereshchagin, L. F. 2256, 2641
Vetter, H. C. 2515
Visich, M., Jr. 2399
Vodicka, V. 2499
Vogeley, A. W. 2477
Volkov, S. D. 2178
von Arx, W. S. 2659
von Karman, T. 2564
Voulman, F. A. 2491
Vovk, A. E. 2629
Vvedenskaya, L. A. 2509
Vyshenskii, V. V. 2525
Wakabayashi, I. 2604
Walker, P. B. 2268
Walker, W. G. 2423
Walz, A. 2397
Wan, K.-S. 2375
Wang, J. 2224
Wattson, R. K., Jr. 2480
Weiberg, J. A. 2456
Weikel, R. C. 2229
Weil, N. A. 2260
Weil, S. A. 2549
Welmers, E. T. 2610
Wicke, M. 2223
Wilk, S. 2476
Wilkins, J. E., Jr. 2500
Wilkinson, J. H. 2125
Williams, H. 2374
Williams, M. R. 2543
Willinski, M. I. 2556
Wilson, C. W. 2546, 2547
Wilts, C. H. 2585
Winter, H. M. 2621
Woo, T. C. 2344
Woods, W. A. 2472
Wray, K. L. 2490
Wright, F. H. 2535, 2537
Wu, C.-S. 2390
Yalin, S. 2681
Yang, K.-T. 2385
Yeh, G. C. K. 2187
Yeh, H. 2443
Yokobori, T. 2260
Yoshikawa, K. K. 2356
Yu, Y.-Y. 2237
Zabetakis, M. G. 2530
Zaid, M. 2190
Zarembo, L. K. 2356
Zarubin, V. S. 2401
Zenkevich, B. A. 2521
Zharmagambetov, B. S. 2217
Zhokhovskii, M. K. 2520
Zhukov, A. M. 2290
Zinkovich, V. P. 2683
Zolotin, Yu. 2631
Zoryan, Z. A. 2431
Zwicky, E. E., Jr. 2107